W. B. No. 695

U. S. DEPARTMENT OF AGRICULTURE

WEATHER BUREAU

CHARLES F. MARVIN, Chief

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SEPTEMBER, 1919

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INTRODUCTION.

The MONTHLY WEATHER REVIEW contains (1) meteorological contributions and bibliography including seismology; (2) an interpretative summary and charts of the weather of the month in the United States and on the adjacent oceans; and (3) climatological and seismological tables dealing with the weather and earthquakes of the month.

The contributions are principally as follows: (a) results of the observational or research work in meteorology carried on in the United States or other parts of the world, in the Weather Bureau, at universities, at research institutes, or by individuals; and (b) abstracts or reviews of important meteorological papers and books, and (c) notes. In each issue of the REVIEW reviews, abstracts, and notes are grouped by subjects, roughly, in the following order: General works, observations and reductions, physical properties of the atmosphere, temperature, pressure, wind, moisture, weather; applications of meteorology, climatology, and seismology.

The Weather Bureau desires that the MONTHLY WEATHER REVIEW shall be a medium of publication for contributions within its field, but the publication of such contributions is not to be construed as official approval of the views expressed.

The partly annotated bibliography of current publications is prepared in the Weather Bureau Library. Persons or institutions receiving Weather Bureau publications free should send in exchange a copy of anything they may publish bearing upon meteorology, addressed "Library U. S. Weather Bureau, Washington, D. C.," in order that the monthly list of current works on meteorology and seismology may be as complete as possible. Similar contributions from others will be welcome. Bibliographies of selected subjects are published from time to time in the REVIEW.

The section on the weather of the month contains (1) an interpretative discussion of the weather of North America and adjacent oceans, and some notes on the weather in other parts of the world; (2) details of the weather of the month in the United States; and (3) brief discussions of weather warnings, rivers and floods, and weather and crops. There are illustrative charts. The climatological tables comprise summaries of the weather and excessive precipitation data for about 210 stations in the United States, and summaries of the weather observed at about 30 Canadian stations.

It is hoped that the meteorological data hitherto contributed by numerous independent services will continue as in the past. Our thanks are due especially to the directors and superintendents of the following:

The Meteorological Service of the Dominion of Canada.
The Meteorological Service of Cuba.
The Meteorological Observatory of Belen College, Habana.
The Government Meteorological Office of Jamaica.
The Meteorological Service of the Azores.
The Meteorological Office, London.
The Danish Meteorological Institute.
The Physical Central Observatory, Petrograd.
The Philippine Weather Bureau.

The seismological tables contain, in a form internationally agreed on, the earthquakes recorded on seismographs in North and Central America. Dispatches on earthquakes felt in all parts of the world are published also.

Since it is important to have as the name of the month appearing on the cover of the REVIEW that of the period covered by the weather discussions and tables rather than that of the month of issue, the REVIEW for a given month does not appear until about the end of the second month following.

SUPPLEMENTS containing kite observations and others containing monographs or specialized groups of papers are published from time to time.

NOTES TO CONTRIBUTORS.

Authors are requested to accompany their papers submitted for publication with a brief opening synopsis. When an article deals with more than one subject—as, for example, a method of measurement—some experimental results and a theory, each subject should be summarized in a *separate paragraph*, with a title which clearly describes it.

When illustrations accompany an article submitted for publication in the MONTHLY WEATHER REVIEW, the places where they should appear in the text should be indicated, and legends or titles for them should be inserted just after the end of the article. As far as practicable the illustrations when accompanied by their legends should be self-explanatory—i. e., the data on them should leave no doubt of what they are intended to convey.

SOME WEATHER BUREAU PUBLICATIONS.

Serial numbers of of Weather Bureau publications........ Free
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Complete monthly number, 42 sections........ 35 c. each, $4 a year
Kite data; 1917, Mo. Wea. Rev. Supplements 10 and 11; 1918, Mo. Wea. Rev. Supplements Nos. 12, 13, 14, and 15........ 25 c. each
The daily weather map, with explanation (text and 4 charts)........ 5 c
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On the relation of atmospheric pressure, temperature, and density to altitude. (Reprinted from Mar., 1919, Mo. Wea. Rev.)........ Free.
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Effect of winds and other weather conditions on the flight of airplanes. (Reprinted with associated papers from Aug., 1919, Mo. Wea. Rev.)........ Free.

As the surplus of MONTHLY WEATHER REVIEW, February, April, and July, 1919, is limited, recipients who do not care to retain their copies will confer a favor by notifying the Chief of Bureau, who will arrange for the return postage.

Chart I. Hydrographs of Several Principal Rivers, September, 1919.

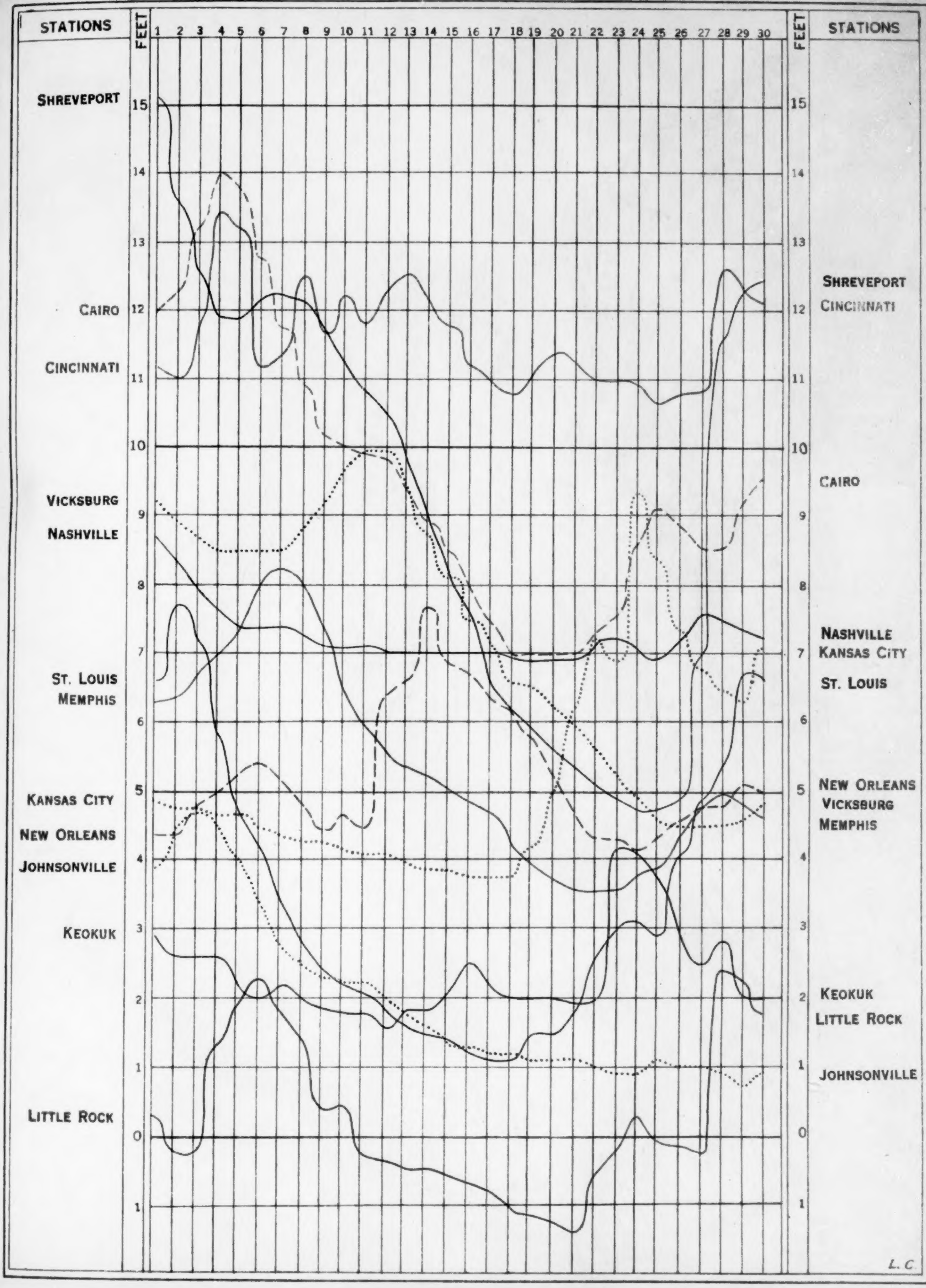


Chart II. Tracks of Centers of High Areas, September, 1919.

(Plotted by R. H. Weightman, Meteorologist.)

Chart III. Tracks of Centers of Low Areas, September, 1919.

(Plotted by R. H. Weightman, Meteorologist.)

NOTE.—In connection with Lows IV and XVII, attention is invited to the fact that reports over the water are meager and scattered, and the pressure readings here presented do not give the minimum pressures at the center, but are merely the readings reported by a vessel which was nearest to the center at the time indicated in the several circles.

Chart IV. Departure (°F.) of the Mean Temperature from the Normal, September, 1919.

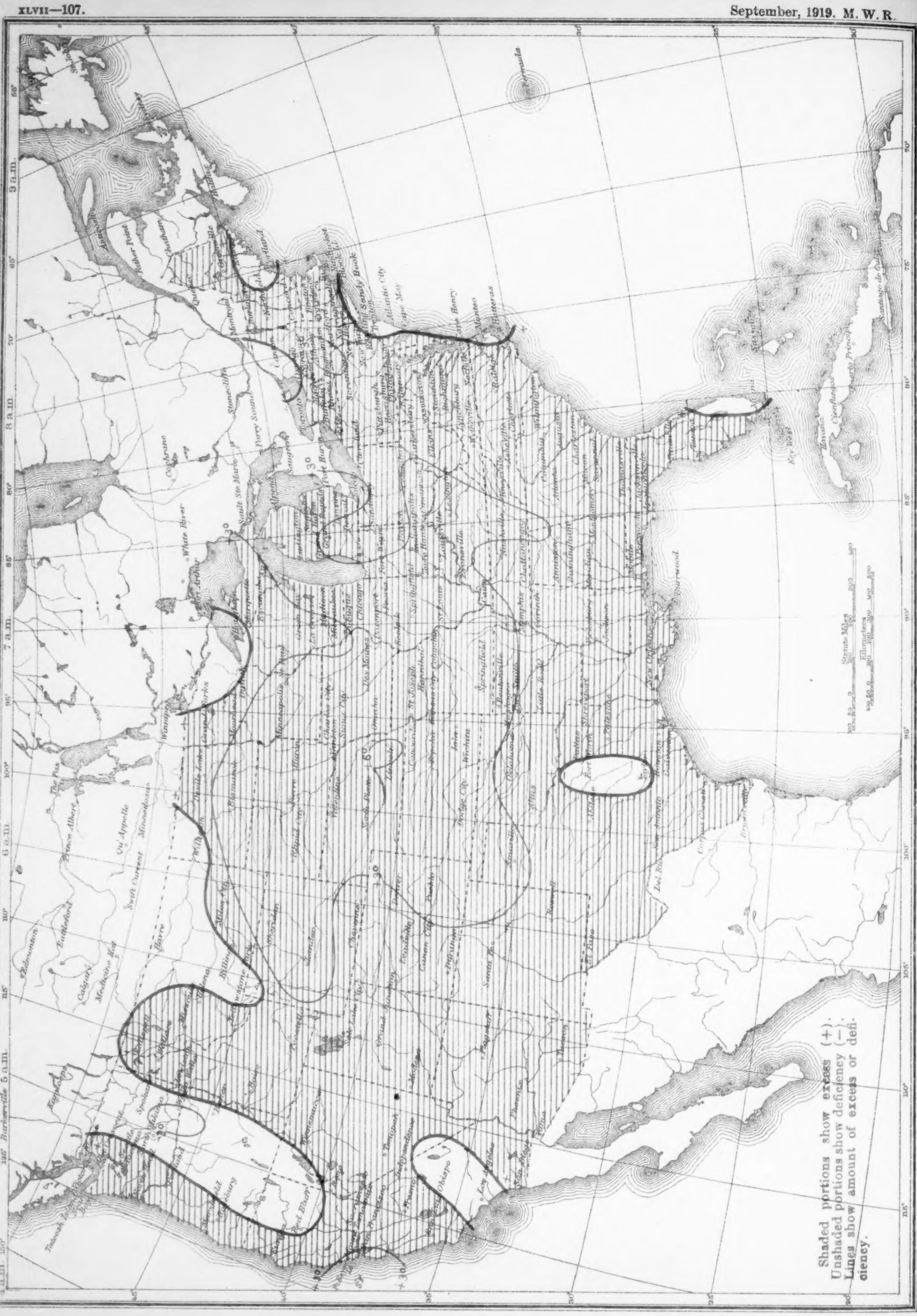
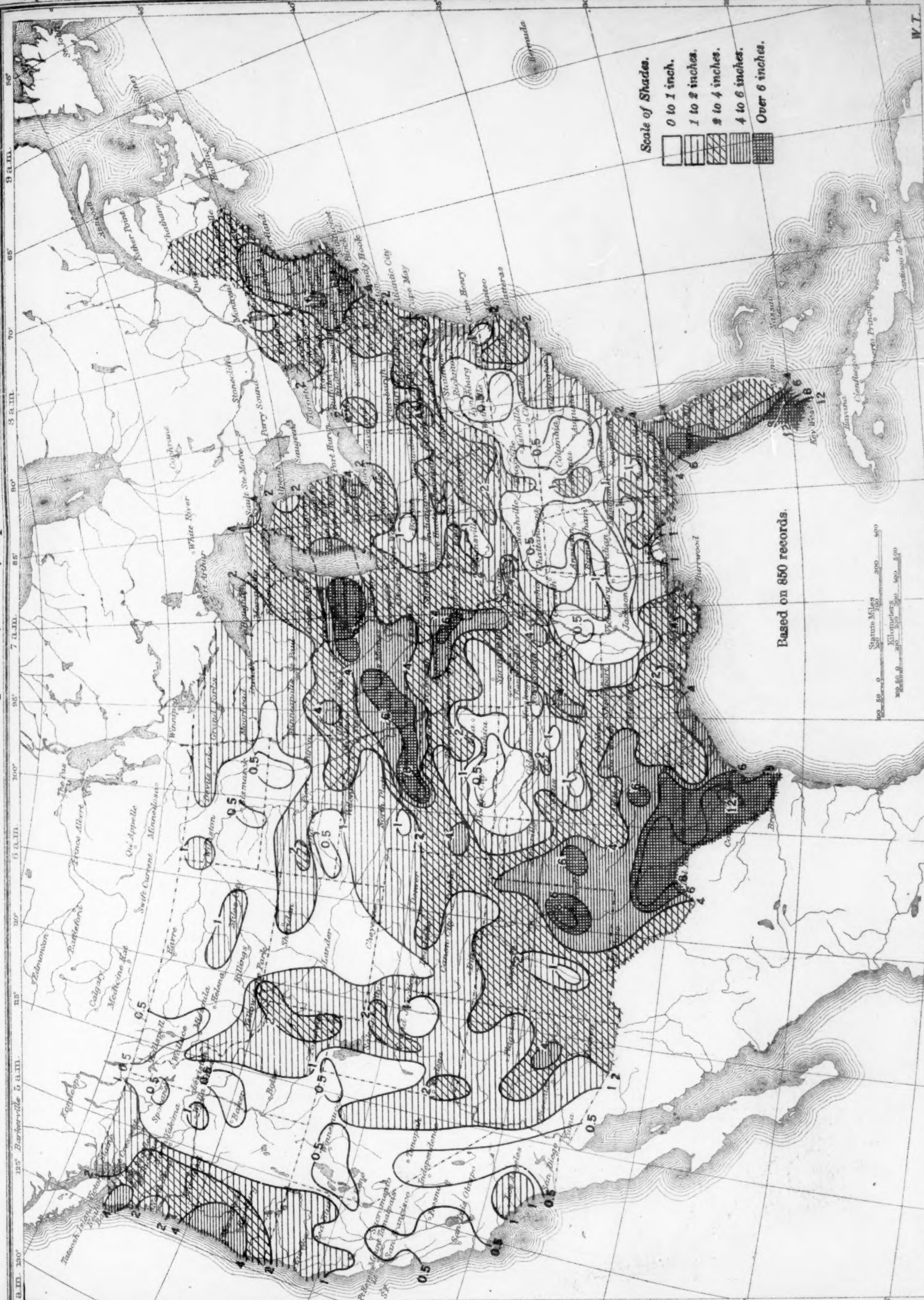


Chart V. Total Precipitation, Inches, September, 1919.



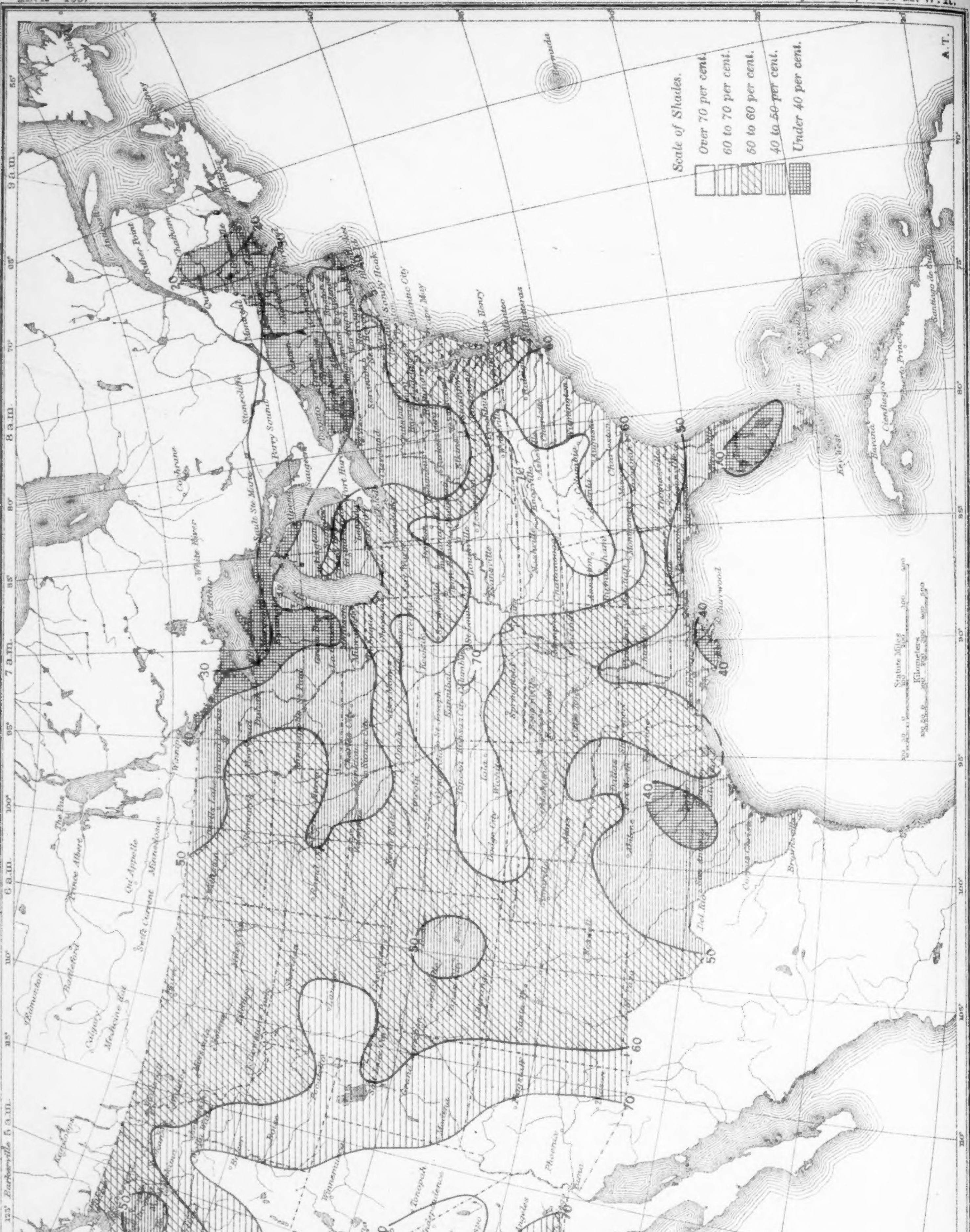


Chart VI. Percentage of Clear Sky between Sunrise and Sunset, September, 1919.

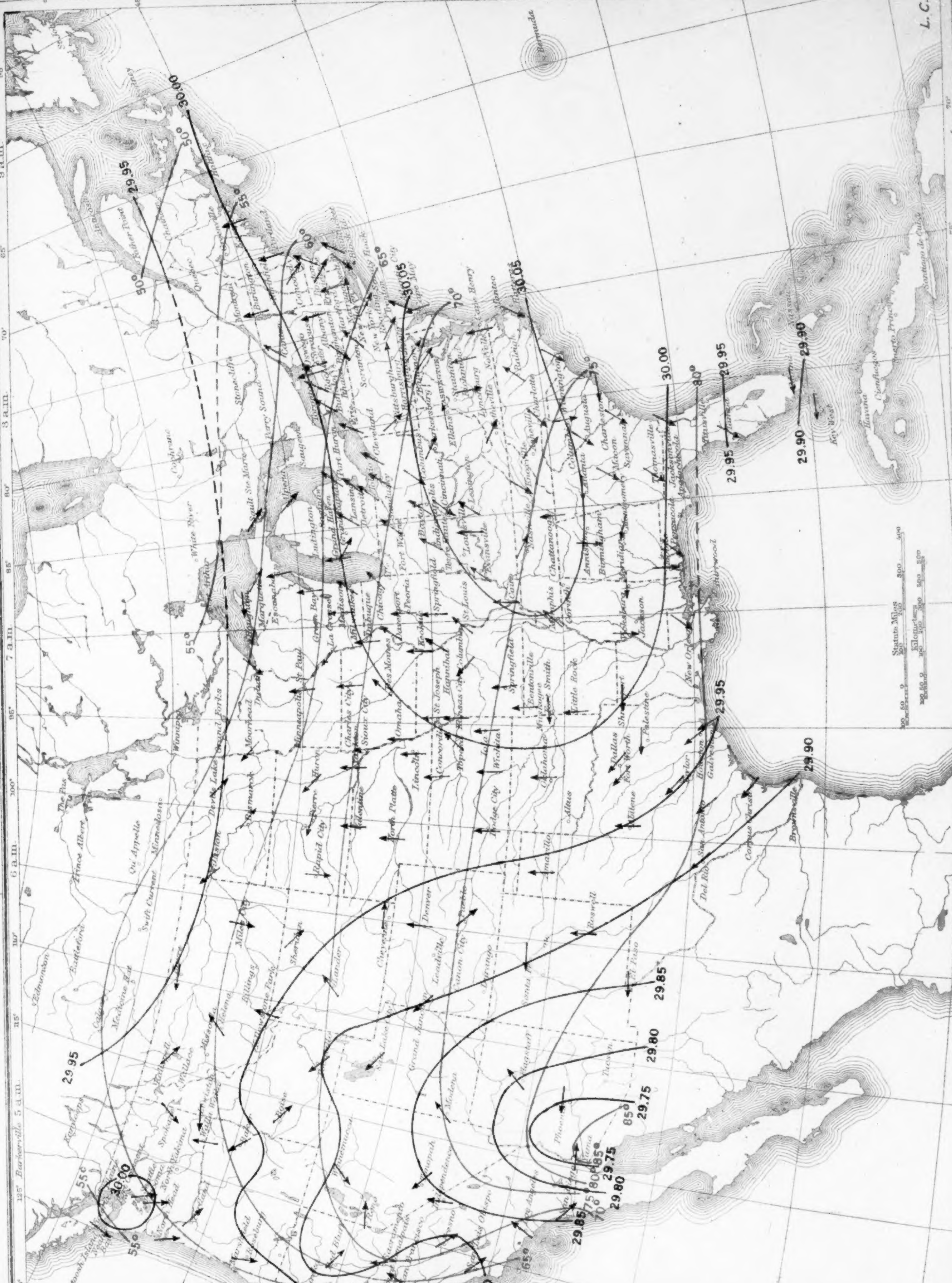


Chart VII. Isobars and Isotherms at Sealevel; Prevailing Winds, September, 1919.

Chart IX. Weather Map of North Atlantic Ocean, September 3, 1919.
(Plotted by F. A. Young.)

Chart IX. Weather Map of North Atlantic Ocean, September 3, 1919.
(Plotted by F. A. Young.)

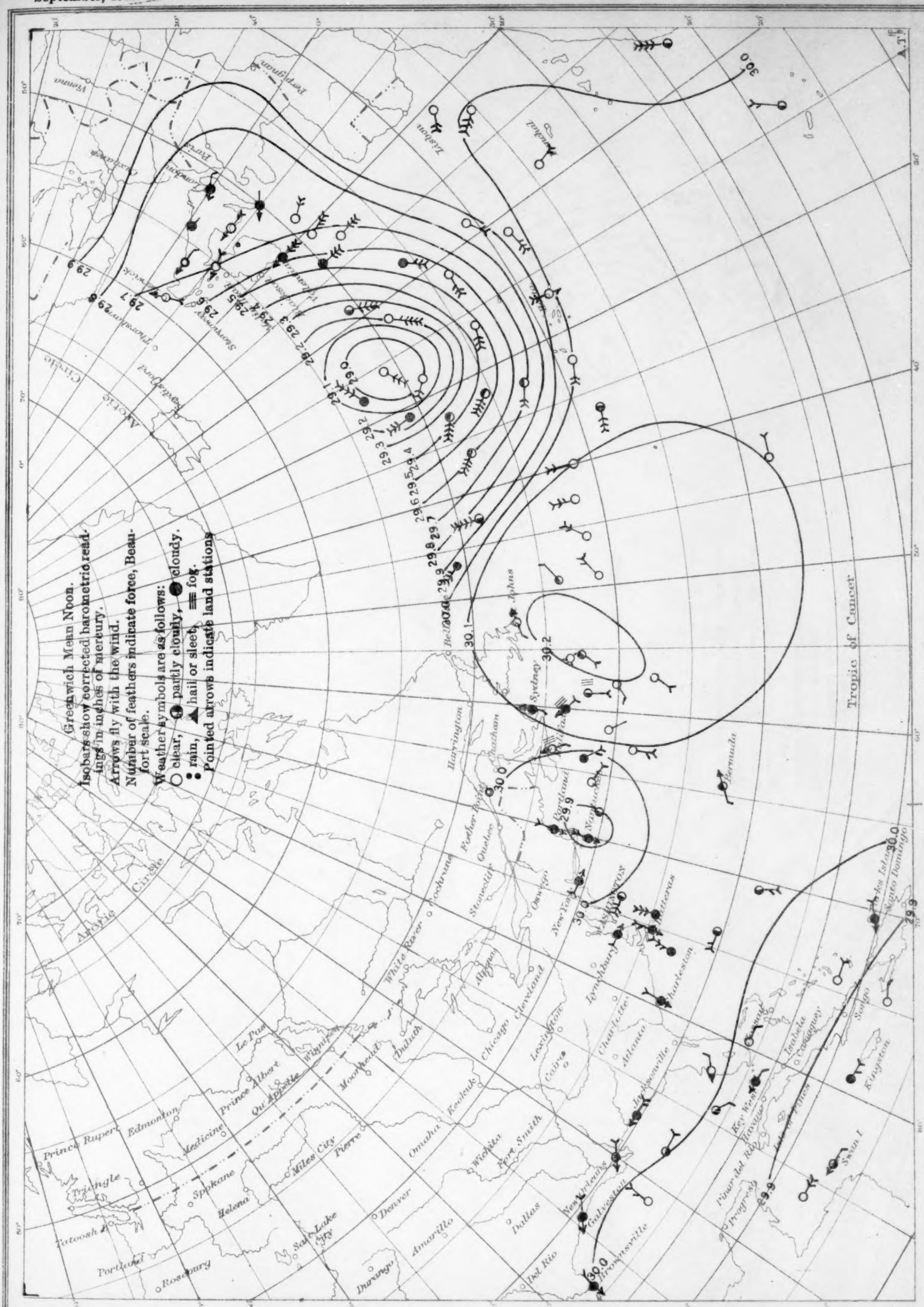


Chart X. Weather Map of North Atlantic Ocean, September 4, 1919.

(Plotted by F. A. Young.)

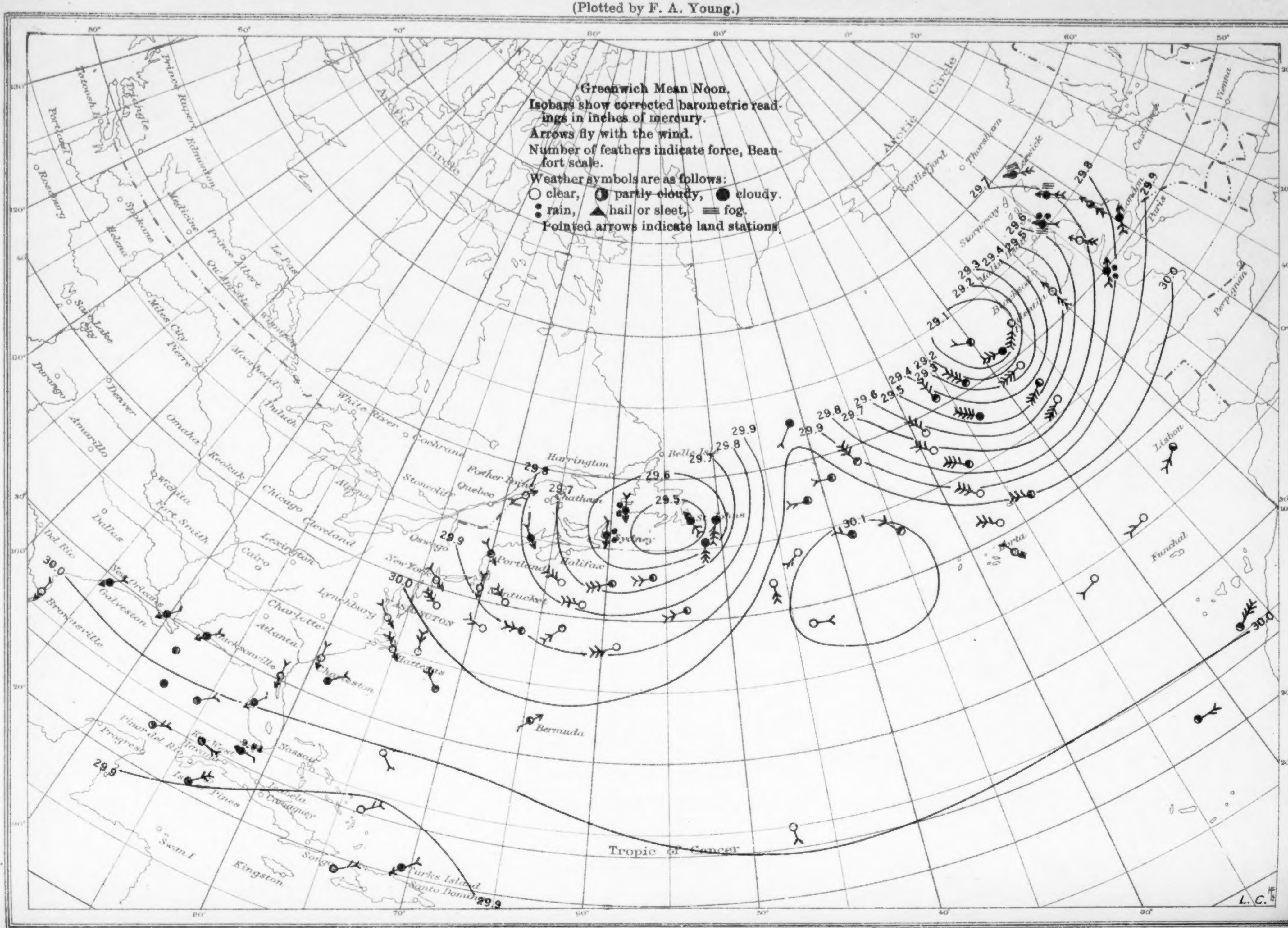


Chart XI. Weather Map of North Atlantic Ocean, September 7, 1919.
(Plotted by F. A. Young.)

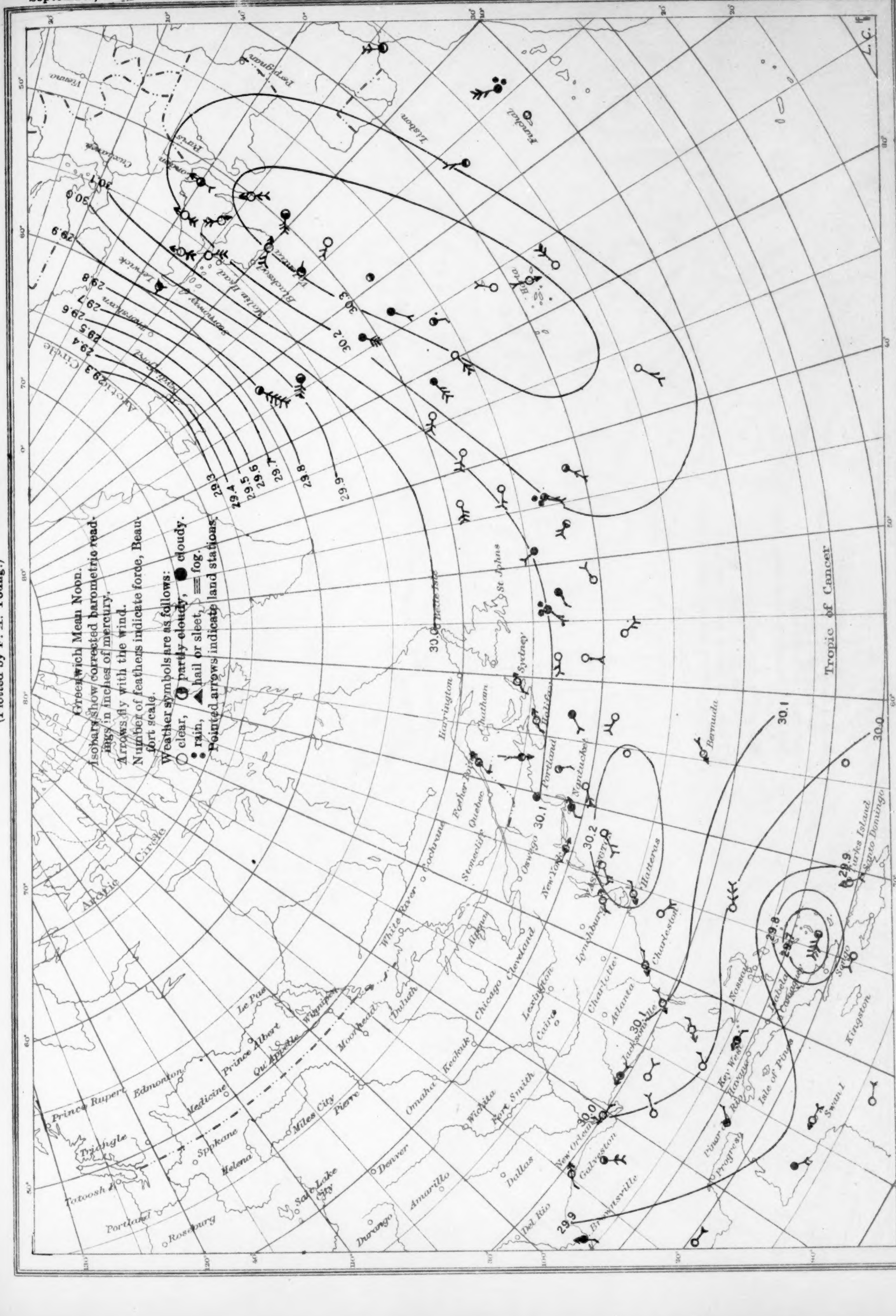


Chart XII. Weather Map of North Atlantic Ocean, September 8, 1919.

(Plotted by F. A. Young.)

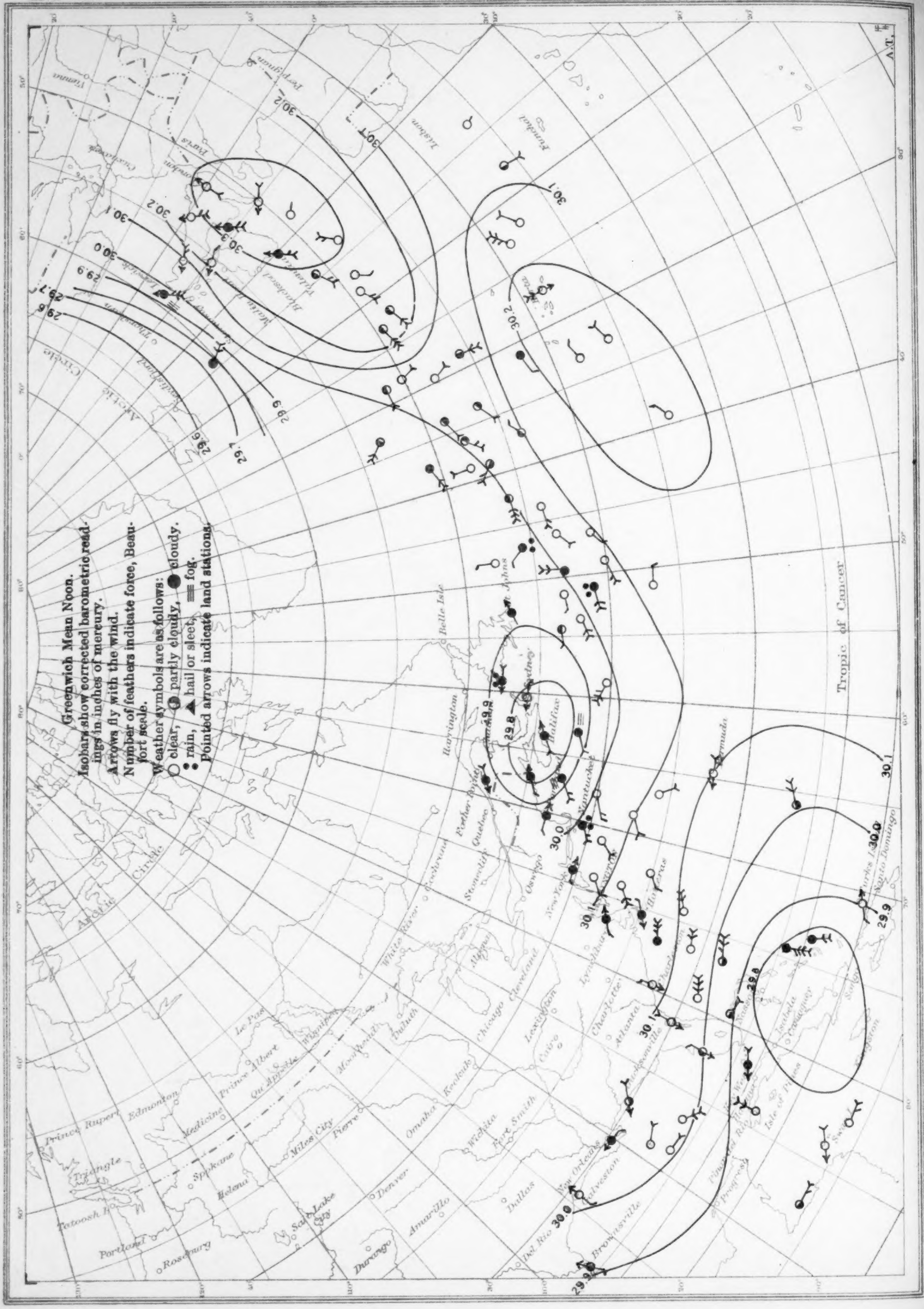


Chart XIII. Weather Map of North Atlantic Ocean, September 9, 1919.

(Plotted by F. A. Young.)

Chart XIII. Weather Map of North Atlantic Ocean, September 9, 1919.

(Plotted by F. A. Young.)

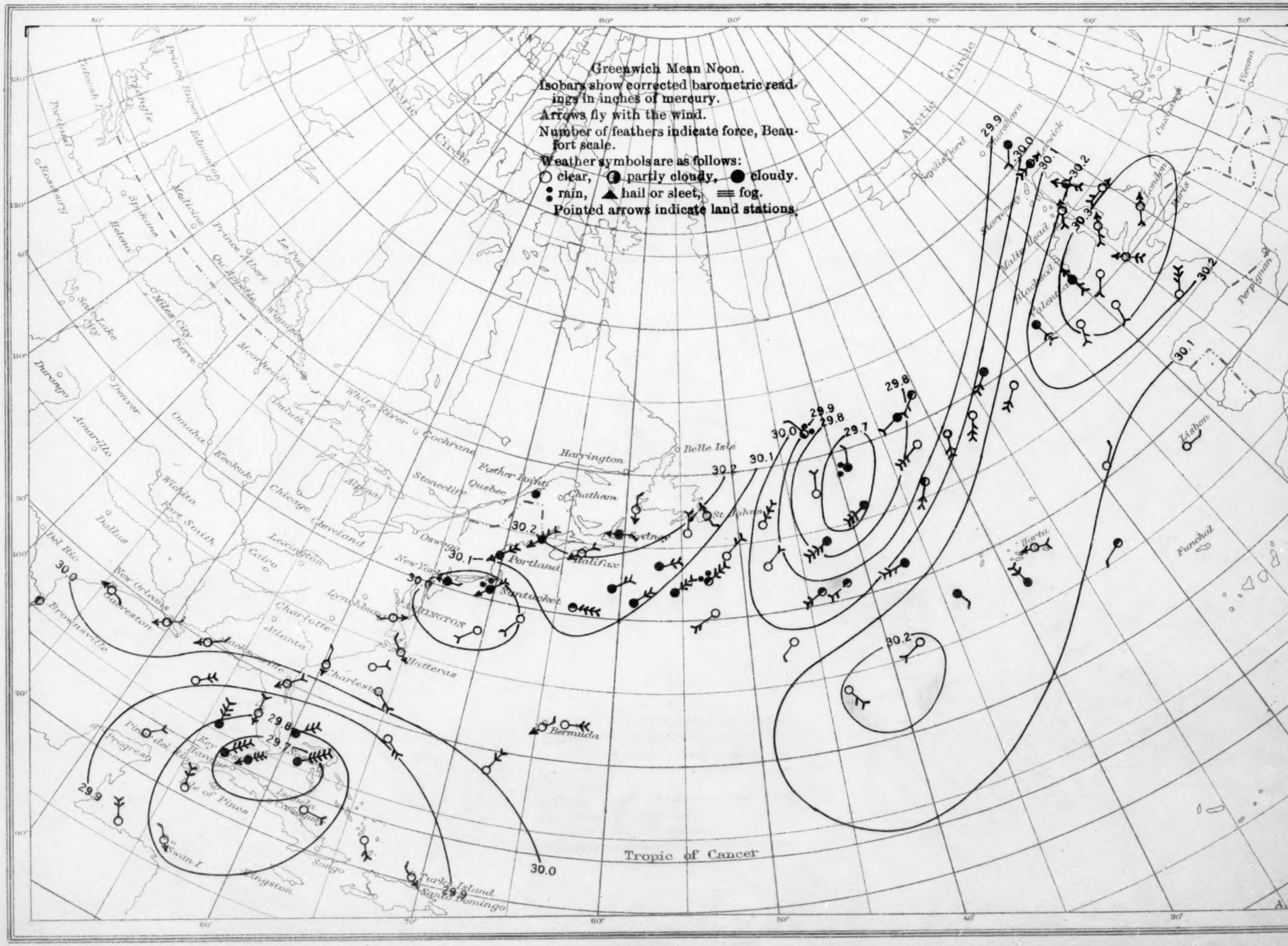


Chart XIV. Weather Map of North Atlantic Ocean, September 10, 1919.

(Plotted by F. A. Young.)

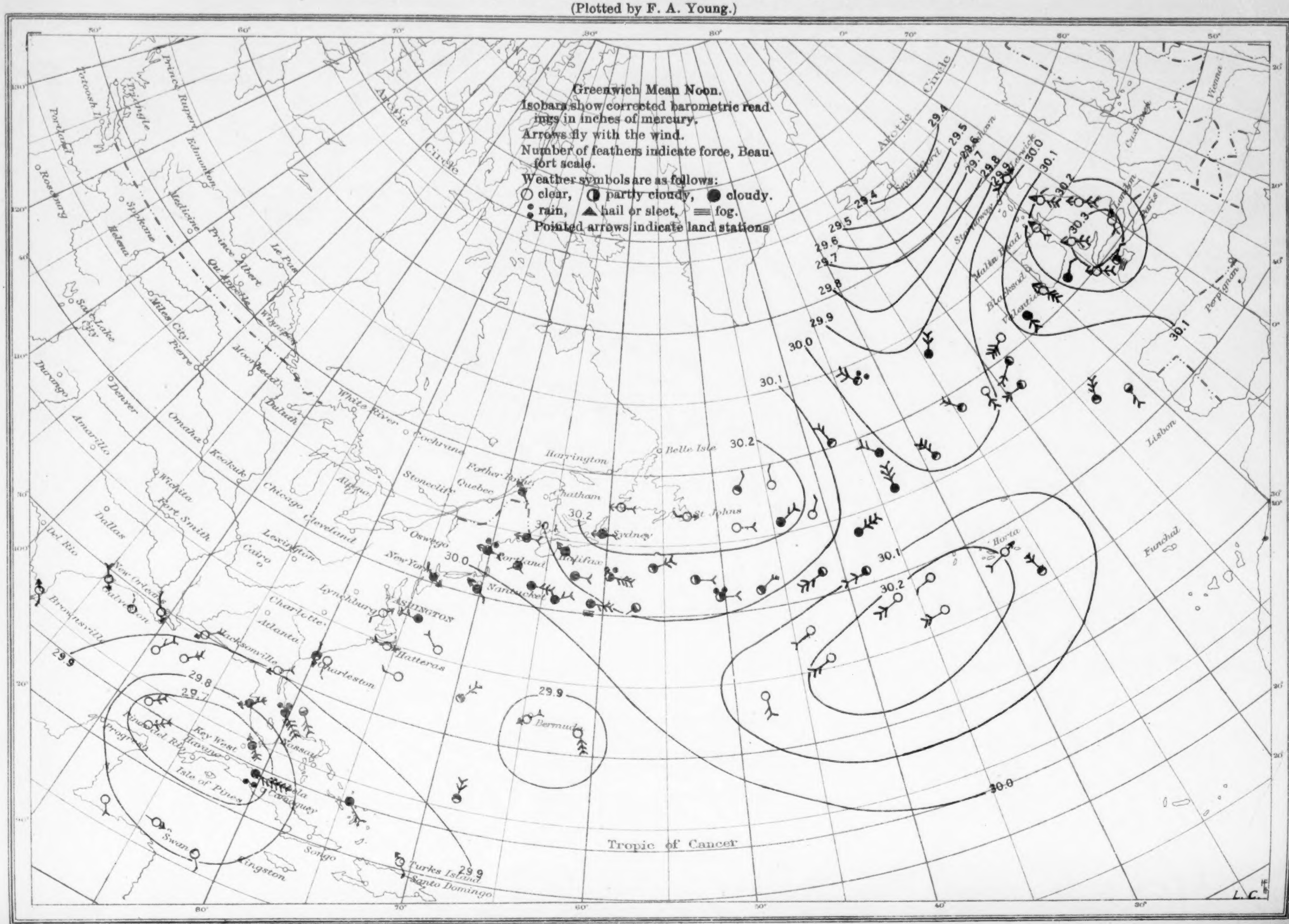


Chart XV. Weather Map of North Atlantic Ocean, September 11, 1919.

(Plotted by F. A. Young.)

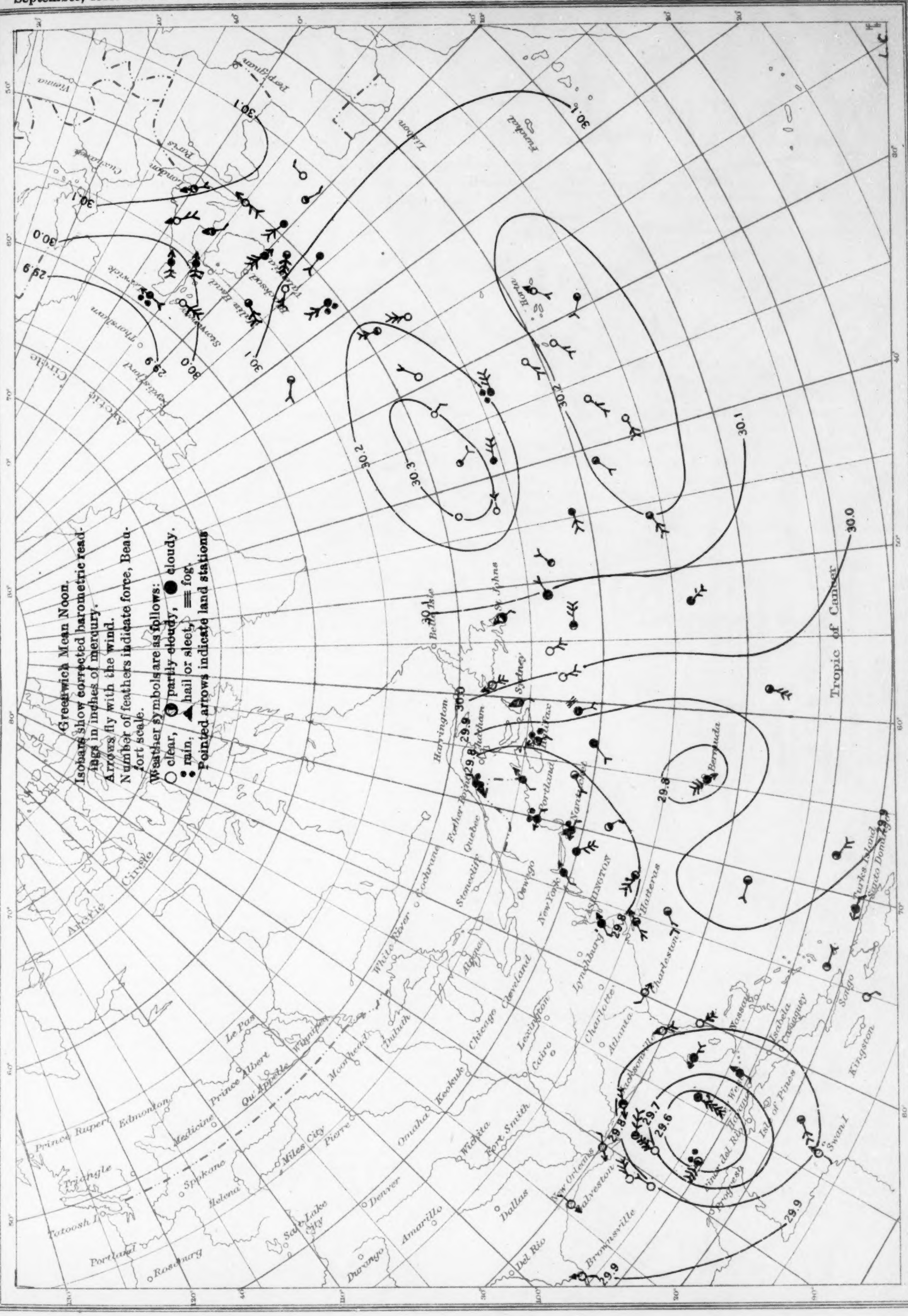
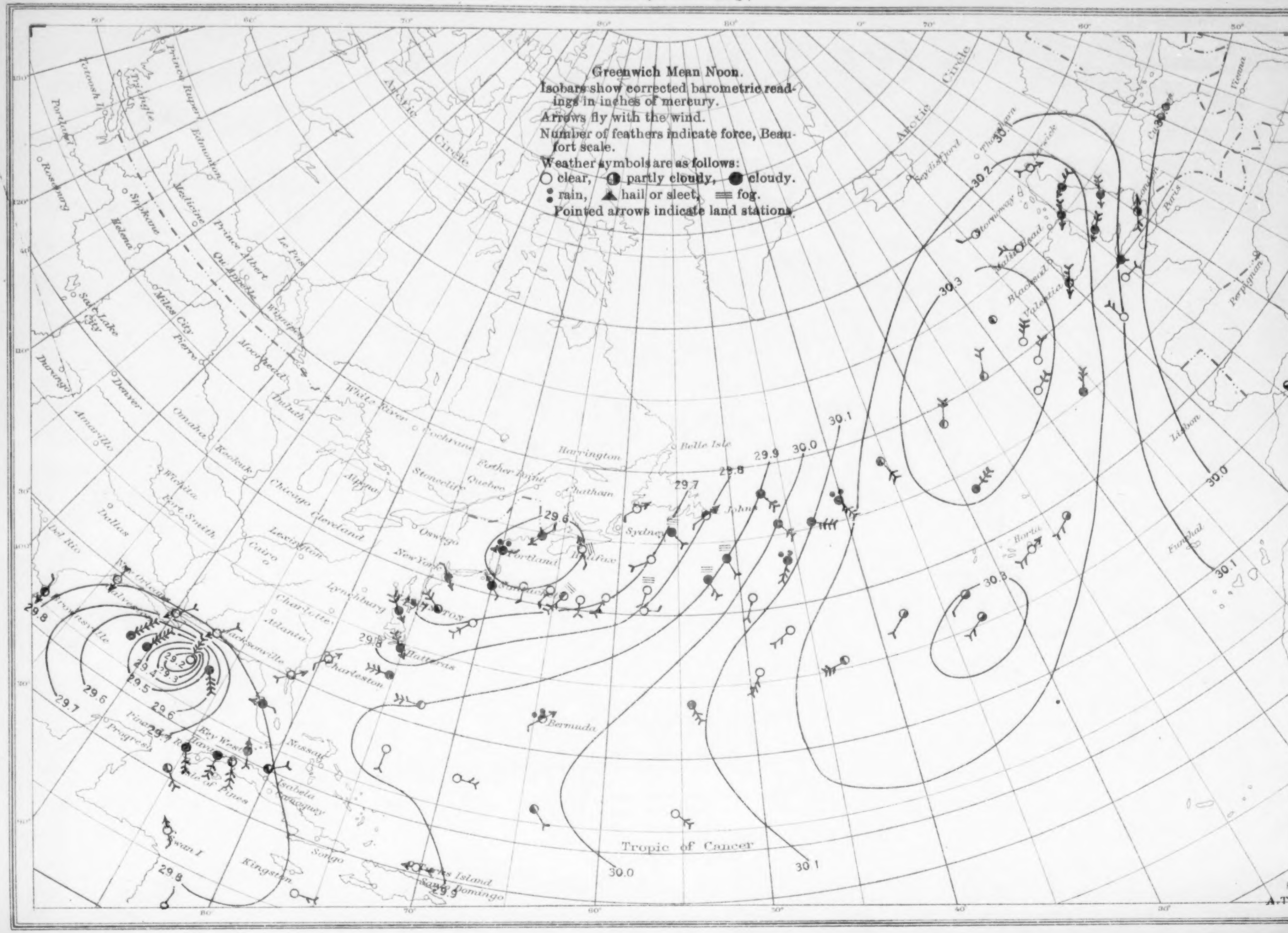


Chart XVI. Weather Map of North Atlantic Ocean, September 12, 1919.

(Plotted by F. A. Young.)



MONTHLY WEATHER REVIEW

CHARLES F. BROOKS, Editor.

VOL. 47, No. 9.
W. B. No. 695.

SEPTEMBER, 1919.

CLOSED Nov. 4, 1919
ISSUED Dec. 16, 1919

RAINFALL INTERCEPTION.

By ROBERT E. HORTON, Consulting Engineer.

[Dated: Albany, N. Y., Sept. 3, 1919.]

SYNOPSIS.—1. Rainfall interception represents a loss of precipitation which would otherwise be available to the soil.

2. The loss takes place through evaporative processes, but may, for convenience, be subdivided into (*a*) interception storage, and (*b*) evaporation during rain.

3. The amount of interception loss is primarily a function of the storage capacity of the plant surface, the duration of precipitation, and the evaporation rate during precipitation.

4. Since there is generally a fairly close correlation between shower duration and amount of precipitation, estimates of interception loss can, for practical purposes, be expressed in terms of precipitation amount per shower.

5. The interception storage loss for trees varies from 0.02 to 0.07 inch per shower, and approaches these values for well-developed crops.

6. The interception storage loss for trees in woods is greater, but the evaporation loss during rain is less than for trees in the open.

7. The percentage of total precipitation loss is greater in light than in heavy showers, ranging from nearly 100 per cent where the total rainfall does not exceed the interception storage capacity to about 25 per cent as an average constant rate for most trees in heavy rains of long duration.

8. Light showers are much more frequent than heavy ones, and the interception loss for a given precipitation in a month or season varies largely, according to the rainfall distribution.

9. Expressing the interception loss in terms of depth on the horizontal projected area shadowed by the vegetation, the loss per shower of a given amount is very nearly the same for various broad-leaved trees during the summer season.

10. The amount of water reaching the ground by running down the trunks of trees may amount to a relatively large volume when measured in gallons for a smooth bark tree in a long heavy rain. It is, however, a relatively small percentage, commonly 1 to 5 per cent, of the total precipitation. The percentage increases from zero in light showers to a maximum constant percentage in heavy showers of long duration.

11. Different interceptometers under the same tree will give fairly consistent results, if so placed that they do not receive direct rainfall, and if they stand under a complete leaf cover of average density.

12. So far as the experimental data go, there is little evidence of watershed effect or dripping of water from the periphery of the crown to a greater extent than through the crown itself.

13. The interception loss from needle-leaved trees, such as pines and hemlocks, is greater both as regards interception storage and evaporation during rain than from broad-leaved trees.

14. The average duration of showers of a given intensity is greatest in winter and the colder summer months, and least in midsummer or thunder-storm months, whereas the evaporation rate is greatest in midsummer and least in the colder months. As a result of the opposite effects of these two factors affecting interception loss, the average loss per shower of a given intensity seems to be nearly constant throughout the different months of the summer period, May to October, inclusive.

15. Data are insufficient for a final determination of the relative losses from trees in winter and in summer. Apparently the winter and summer losses for a given monthly precipitation for needle-leaved trees are about equal, whereas for deciduous, broad-leaved trees the winter interception loss appears to be about 50 per cent as great when the trees are defoliated as during the growing season.

16. Interception loss from full-grown field crops approaches in value that from trees, but owing to the short time during which crops stand on the ground in a fully developed stage of growth, the total annual interception loss from cropped areas is very much smaller than from wooded areas.

17. The average interception loss from 11 trees, excluding peripheral interceptometers and excluding hickory, for which the results are defective, during the summer of 1918 was 40 per cent of the precipitation.

INTRODUCTION.

A large amount of data has been accumulated on this subject. There does not appear, however, to have been any thorough and complete analysis of all the available data, and it is unfortunate that not even a reasonably complete digest of the experimental observations is available in English. Furthermore, the processes involved do not seem to have been carefully analyzed, and, as a result, many of the experimental data are not in a form permitting interpretation of the results to the best advantage.

The subject is one on which it is somewhat difficult to experiment in a satisfactory manner, and it is not surprising that the conclusions hitherto drawn by different authorities are sometimes at variance, and many of the data are seemingly discordant.

TABLE No. 1.—*Summary of rainfall interception data for forests.*

Wood.	Per cent loss.			Station, duration, authority, etc.
	Winter.	Summer.	Year.	
(1)	(2)	(3)	(4)	(5)
Mixed			25	16 German stations(ref. 1), p. 106.
Do			16	3 Swiss stations (ref. 1) 16-year average, p. 106.
(?)			16	Nancy, Bellefontaine, 11 years.
Evergreens	20.90	[1] 26	[2] 23	German stations (ref. 1), p. 107.
Deciduous	19.60	[1] 35	[2] 26	Do.
General average	21.40	[1] 30	[2] 25	
Larch			15	Swiss stations, 12 years (ref. 1), p. 131.
Spruce			23	
Beech			10	
Do			24	Prussian stations (ref. 1), p. 131.
Spruce			27.7	Do.
Do			39	Raphael Zon (ref. 10), p. 230.
Broad leaved			13	Raphael Zon.
Beech			15	Raphael Zon, from Ney; crown loss after deducting trunk run-off (ref. 10), p. 230.
Pine			20	
Spruce			33.33	
Blue beech	5.85		8.48	Mathieu at Nancy, 11 years (ref. 10, p. 231).
Beech, 20-year			2	Bühler, 2 to 3 years (ref. 10, p. 230).
Beech, 50-year			27	
Beech, 60-year			23	
Beech, 90-year			17	

a Forest influences.
b Final report National Waterways Commission.
[1] May-Sept. 5/12 year.
[2] Approximate, deduced by proportion from columns (2) and (3).

Table No. 1 contains a digest of the results of different experiments, and of the conclusions of different authorities therefrom.

In comparison with some of the European results, the following statement by H. S. Graves is pertinent: (Monthly Weather Review, Dec., 1914, 42: 671).

Many and exact measurements have demonstrated that a forest cover intercepts from 15 to 80 per cent of

the precipitation, according to the species of trees, density of the stand, age of the forest, and other factors. Thus pine forests of the North intercept only about 20 per cent, spruce about 40 per cent, and fir nearly 60 per cent of the total precipitation that falls in the open, the amount that runs off along the trunks in some species is very small, less than 1 per cent, in others, beech for instance, it is 5 per cent.

Harrington in Forest Influences, (**1**) says:

"It seems that the deciduous trees withhold more of the precipitation through the entire year than do the evergreens."

Zon (**10**) states:

"As a result of a great number of investigations it may be assumed that coniferous forests intercept more precipitation than broad-leaved forests."

Imbeaux gives the opinion that the interception loss is 50 per cent in coniferous, and 20 to 30 in deciduous woods. (Essai-Programme of Hydrology.)

PHYSICS OF RAINFALL INTERCEPTION.

It is a matter of common observation that the percentage of precipitation reaching the ground in forest or on fields with growing crops is very small in the earliest stages of a rain, increasing as the duration of the storm increases, the total amount reaching the ground being small for short light showers, and increasing for severe prolonged storms. General observations also lead to the following conclusions:

When rain begins, drops striking leaves are mostly retained, spreading over the leaf surfaces in a thin layer or collecting in drops or blotches at points, edges, or on ridges or in depressions of the leaf surface. Only a meager spattered fall reaches the ground, until the leaf surfaces have retained a certain volume of water, dependent on the position of the leaf surface, whether horizontal or inclined, on the form of the leaf, and on the surface tension relations between the water and the leaf surface, on the wind velocity, the intensity of the rainfall, and the size and impact of the falling drops. When the maximum surface storage capacity for a given leaf is reached, added water striking the leaf causes one after another of the drops to accumulate on the leaf edges at the lower points. Each drop grows in size (the air being still) until the weight of the drop overbalances the surface tension between the drop and the leaf film, when it falls, perhaps to the ground, perhaps to a lower leaf hitherto more sheltered. These drops may also be shaken off by wind or by impact of rain on the leaf. The leaf system temporarily stores the precipitation, transforming the original rain drops usually into larger drops. In the meantime the films and drops on the leaves are freely exposed to evaporation.

It is evident that the amount of interception in a given shower comprises two elements. The first may be called interception storage. If the shower continues, and its volume is sufficient, the leaves and branches will reach a state where no more water can be stored on their surfaces. Thereafter, if there is no wind, the rain would drop off as fast as it fell, were it not for the fact that even during rain there is a considerable evaporation loss from the enormous wet surface exposed by the tree and its foliage. As long as this evaporation loss continues and after the interception storage is filled, the amount of rain reaching the ground is measured by the difference between the rate of rainfall and the evaporation loss. When the rain ceases the interception storage still remains on the tree and is subsequently lost by evaporation. If there is wind accompanying the rain, then, owing to motion of the leaves and branches, it is probable that the maximum interception storage capacity for the given tree is materially reduced as compared with still air conditions. Furthermore, in such a case, after the rain has ceased, a part of the interception storage remaining on the tree may be shaken off by the wind, and the storage loss in such a case is measured only by the portion of the interception storage which is lost by evaporation and is not shaken off the tree after the rain has ceased. One effect of wind is, therefore, to reduce materially the interception storage. As regards evaporation loss during rain, the effect of wind is, of course, to increase it materially.

The difference between interception losses with and without wind is illustrated by the accompanying figure 1. If there is no wind, and the rain falls gently, it is nearly all intercepted until the interception storage capacity is reached—thereafter in the absence of wind, evaporation proceeds slowly, the remainder of the precipitation dripping off the leaves, generally in large drops, and reaching the ground. For a sharp shower with wind, the interception storage is filled only to a limited extent, drops being temporarily stored on the leaves and then shaken off. The evaporation rate may, however, be materially increased, so that while the depth of interception during the earlier part of the storm is likely to be less than for a storm without wind, the total interception depth for a long-continued storm with wind may be the greater of the two, owing to increased evaporation.

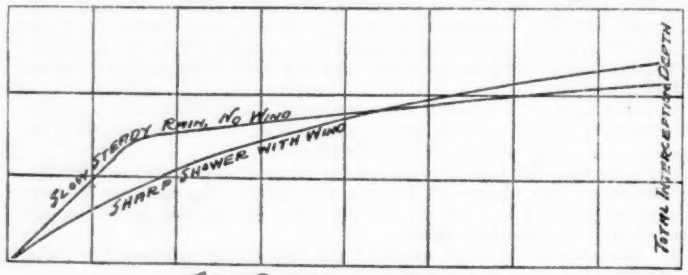


FIG. 1.—The effect of wind and character of shower on interception loss.

The maximum interception storage can be approximately determined from records taken for short, light showers, during which nearly all the rainfall was intercepted.

The fundamental storage equation—inflow equals outflow plus gain, or, minus loss of storage—applies to this process, but after the leaf storage is saturated, leaves are freely exposed to evaporation, the inflow rate minus evaporation rate equals outflow rate.

For the storm as a whole, the following relation holds: Inflow minus total evaporation during storm equals total outflow plus leaf storage at end of storm.

It will be seen that during the greater portion of a long rain capable of producing a severe storm, run-off rate equals precipitation rate minus evaporation rate. In general, for a storm sufficient to saturate the leaf storage.

Total interception equals leaf storage capacity plus evaporation loss during the storm.

Owing to the great extent of leaf surface, the evaporation loss from leaf surfaces is much greater than from the projected area shaded by the tree, but is likely to be relatively small per unit of exposed surface compared with the evaporation rate in fair weather, owing to the smaller saturation deficit common during rain, and the approximate equality between leaf-surface and air temperature.

The superficial storage capacity of a plant is approximately constant at a given stage of growth or leaf development. By storage capacity is meant the depth of water on the projected area covered by the plant which can be stored or detained on the plant surface in still air.

If T = duration of the storm in hours.

E_r = evaporation rate in inches depth per hour during the storm.

K_1 = ratio of the evaporation surface to the projected area.

S_j = interception storage capacity in inches depth on the projected area.

P = precipitation rate per unit of time.

Then the total interception loss is—

$$J = S_j + K_1 E_r T \tag{1}$$

and the percentage loss—

$$\frac{J}{PT} = \frac{S_j + K_1 E_r T}{PT} \tag{2}$$

This formula indicates that the percentage loss decreases as the duration of the storm increases; and furthermore, since the numerator is independent of the rain intensity, the percentage loss decreases as the intensity of the storm increases.

Following this reasoning, we should expect the percentage of rainfall intercepted to be less for heavy rain than for light rains. Zon states this to be a fact (*a*) (**10**) but he does not give any data in support of his conclusions. Most of the data hitherto published in the form in which presented are quite doscordnat as regards the relation of rainfall intensity to amount of interception, but this is quite certainly due in part to the presentation of results in monthly or seasonal totals regardless of rainfall distribution.

THE CHARACTER OF INTERCEPTION STORAGE ON DIFFERENT PLANTS.

Observation and sketches were made of the amount of water accumulated on different plant surfaces after a rainfall on July 12, 1915, of 0.12 inch at night, with no wind. Sketches of typical leaves, showing the mode of water storage or accumulation thereon, are contained in the accompanying fig. 2.

Leaves of different plants vary greatly in the manner in which rain falling on them is retained. Many leaves become wetted over their entire upper surface with a thin film of water which is not shown in the sketches. There does not seem to be any regular rule as to this, as leaves which appear bright and waxy as well as others having dull surfaces both become wetted in some cases, whereas in other cases, according to the configuration of the surface of the leaf, water accumulates on both classes of leaves only in drops or blotches. Of course, water tends to accumulate in capillary spaces of all forms. In some cases where the entire leaf surface becomes wetted the film thickens in the depressions along the lines of the veins. More generally the entire leaf surface does not become wetted, and in such cases the water which accumulates in drops on the leaf surfaces is mostly concentrated on the plateaus or ridges between the lines of veins. Apparently the majority of leaves do not become appreciably wetted on the underside, excepting where drops and blotches overflow from the edges.

The possibilities of interception storage are revealed by observations by the author on July 12, 1915, of more than 100 water drops retained per leaf on leaves of horsechestnut, oak, and aspen, in addition to blotches and films, and 100 or more drops on single stems of rye.

During the defoliated season the author has observed large drops about 1 inch apart clinging after a cold rain to the underside of every twig or horizontal branch of a maple. In warm weather this water runs off more easily and the interception storage is then largely on leaf surfaces.

An approximate estimate of the interception storage can be arrived at by counting the number of drops per unit of plant surface, estimating their diameter and volume.

Volumes of small spheres per million

Diameter.	Volume per million.
In inches.	*Cubic inches.*
1/32	15.98
1/16	127.83
3/32	450.40
1/8	1,022.60
5/32	2,085.00
3/16	3,451.40
7/32	5,721.20
1/4	8,181.20

For example, a crop of rye containing 3,000 stalks per acre, with storage equal to one hundred and twenty ⅛-inch drops per stalk, would contain, exclusive of water in the heads, 213.1 cubic feet of interception storage per acre. This is equivalent to a depth of 0.047 inch on the surface.

Again, a tree having one-half million leaves, with an average of twenty ⅛-inch diameter drops per leaf, would contain 5.92 cubic feet of interception storage. If the crown diameter was 40 feet, the projected area being 1,256 square feet, the interception storage would be equivalent to 0.0564 inch.

EXPERIMENTAL DATA OF INTERCEPTION.

In order to determine the numerical factors for calculating interception losses, an effort was first made to utilize existing experimental data. For this purpose, the interception records for the Adlisberg and Haidenhaus forest meteorological stations were analyzed for the years 1889 and 1890. The recorded precipitations on each day when rain fell were grouped together according to the amount of precipitation at the station in the open, averages for each group were taken both for the station in open and for stations in the forest.

TABLES 2, *A*, *B*, *C*.—*Analysis of Adlisberg records precipitation arranged by daily amounts caught by gage in open, in inches.*

Range mm. per day.	Average inches per day.	Beech (1).	Beech (2).	Beech (3).	Average beeches (2) and (3)
(1)	(2)	(3)	(4)	(5)	(6)
B—BEECHES, SUMMER PERCENTAGES CAUGHT.					
0–15	0.10	[1] 92.80	77.30	79.60	78.45
5–10	.30	95.51	78.59	83.91	81.25
10–20	.60	93.41	80.50	87.50	84.00
Over 20	.90	86.20	80.44	85.30	[2] 82.37
A—BEECHES, WINTER PERCENTAGES.					
0–5	0.10	97.30	72.05	80.43	71.24
5–10	.30	100.00	64.15	68.27	66.21
10–20	.60	70.63	42.25	51.88	47.06
Over 20	.90	87.51	....	....	....
C—FIRS, PERCENTAGES CAUGHT.					
		Winter.	*Summer.*		
0–5	0.10	42.95	52.50	....	....
5–10	.30	44.65	68.90	....	....
10–20	.60	54.76	84.10	....	....
Over 20	.90	75.74	79.80	....	....

[1] For full two-year period. [2] Number of observations small.

Winter and summer records were separated, the six months period, November to April, inclusive, being counted as winter. Tables No. 2, A, B, and C contain a summary of these studies. The results for fir trees, Table 2 C, show a fairly consistent increase in the percentage of precipitation reaching the ground as the rainfall in inches per day increases. This is true in the case of fir for both winter and summer conditions. In the case of beech trees, one station was maintained throughout the whole period, and two additional stations during the year 1890.

Station No. 1 for beech, which covers the entire period, shows in the case of many storms a measured precipitation greater than that in the open. The average percentage of rainfall reaching the ground for station No. 1 under beech is indicated in column (2) of Tables 2 B and 2 A, respectively. It will be noted that the percentage reaching the ground under beech, station No. 1, is much larger than the percentage reaching the ground under beeches Nos. 2 and 3, and this is indicated by columns (3) and (4) of the same tables.

If station No. 1, for beech, is included, the average for the three stations does not show any consistent relation between rainfall intensity and amount of interception loss. Excluding station No. 1, the record for beeches shows a fairly consistent but small increase in the percentage of rainfall reaching the ground, with increased rainfall rate during the summer season, as indicated by column (5) of Table 2 B. The results fail, however, to show a consistent increase; and show, in fact, a consistent apparent decrease in percentages for the mean of beech at stations Nos. 2 and 3, for winter conditions. In

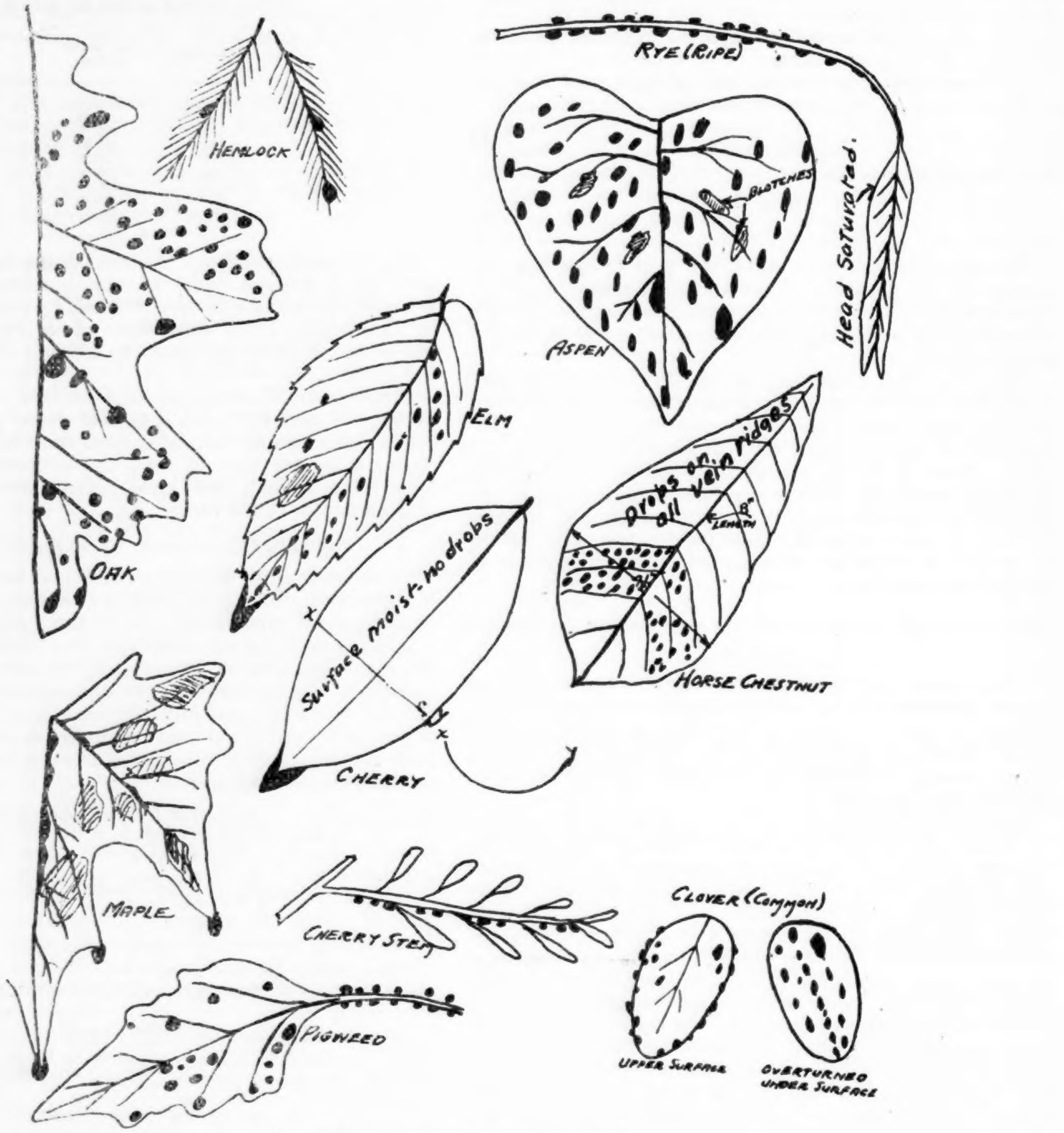


FIG. 2.—Interception storage on various plants.

general it appears that the *a priori* conclusion is fairly confirmed by these experiments as well as could be expected, taking into account the evident large experimental errors existing.

Interception by beech crowns of different ages (Bühler).

	Age of stand, years.			
	20	50	60	80
Proportion reaching ground	0.98	0.73	0.77	0.83
Proportion intercepted	.02	.27	.23	.17

Taking the Adlisberg records by months, arranged in order of magnitude by rainfall rates, we find, for the summer, the following:

TABLE No. 3.—*Monthly precipitation caught under trees, per cent of that in the open, Adlisberg.*

Inches.	Days.	Rate.	Per cent caught.				
			Fir.	Beech (1).	Beech (2).	Beech (3).	Mean, Beech (2) and (3).
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
2.23	20	0.111	57.2	90.7	73.4	78.5	75.9
4.33	20	.217	77.2	107.2	77.5	89.4	83.4
4.21	17	.240	72.6	94.0	75.4	83.0	79.2
5.08	14	.360	95.2	87.0	82.6	85.8	84.2
1.47	4	.370	90.2	96.0	82.6	97.6	90.2
9.42	19	.480	78.6	94.4	74.9	80.0	77.5

This table shows a general tendency to increase in percentage of rainfall caught by gage in forest as rainfall rate increases. The same is true at Haidenhaus, as indicated by Table No. 4.

The Adlisberg and Haidenhaus records both show an apparent decrease in percentage caught in the forest in winter as the rate per storm increases.

TABLE No. 4.—*Haidenhaus interception data; analysis of monthly records on basis of average rainfall rate per storm day.*

Precipitation in open.			Precipitation in forest, per cent of open.	
Inches.	Days.	Inches per day.	Deciduous.	Evergreen.
(1)	(2)	(3)	(4)	(5)
WINTER.				
0.18	3	0.06	102.2	22.2
1.16	11	.105	86.8	56.2
1.33	3	.11	157.0	78.0
2.62	22	.12	73.4	26.3
3.02	17	.17	80.2	53.7
SUMMER.				
2.65	18	0.146	61.7	42.8
4.73	21	.225	70.2	45.6
1.55	6	.26	70.3	57.6
4.89	15	.326	70.0	56.0
5.36	13	.41	71.0	62.8
9.30	20	.46	77.2	58.2

THE AUTHOR'S EXPERIMENTS ON INTERCEPTION.

The data of interception thus far reviewed are in the form of annual, monthly, or, at best, daily averages. Published data of rainfall interception in individual showers are meager. The following observations were made by Seckendorff during a continuous downpour of rain, which lasted from the morning of June 12th to the night of June 14th. The total precipitation was 52.6 millimeters (2.07 inches).[1]

Interception of rainfall by trees.

Tree.	Precipitation in inches.	Percentage reaching ground.	
		Not including water running down tree trunk.	Including water running down tree trunk.
Beech	2.07	54.0	61.6
Oak	2.07	62.5	68.9
Maple	2.07	65.2	69.4
Pine	2.07	30.6	31.6

In order to provide data for analysis on the basis of individual showers the experiments described below were carried out.

TABLE 5.—*Summary of Ebermayer's experiments on rainfall interception.*

Station.	Forest.	Precipitation in open, inches per month.		Percentage caught in forest.		Loss per cent.		Precipitation in forest.	
		Winter.	Summer.	Winter.	Summer.	Winter.	Summer.	Winter.	Summer.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Seeshaupt	40-year-old fir	2.55	3.28	68.6	76.2	41.4	23.8	1.75	2.50
Duschelberg	40-year-old pine	6.79	2.73	73.6	72.5	26.4	27.5	5.00	1.98
Ebrach	50-year-old pine	2.86	1.61	90.6	69.6	9.4	30.4	2.59	1.12
Altenfurth	Wild pine	2.34	1.83	75.4	68.9	24.6	31.1	1.765	1.26
Mean, evergreens		3.64	2.36	77.05	71.8	22.95	28.2	2.78	1.72
Johanneskreutz	60-year old beech	3.49	3.16	72.5	79.0	27.5	21.0	2.53	2.50
Rohrbrunn	60-year-old beech	4.04	2.96	80.0	82.4	20.0	17.6	3.23	2.44
Mean, beech		3.76	3.06	76.25	80.7	23.75	19.3	2.88	2.47

[1] Lueger, Wasserversorgung der Städte.

During the period July to November, inclusive, 1917, and April to October, inclusive, 1918, interceptometers were maintained under trees of various kinds at the hydrologic laboratory of the author near Albany, N. Y. The accompanying map, fig. 3, shows the positions of the different trees and the accompanying Table No. 6 gives the size of each tree and other details. The rain gages used as interceptometers were galvanized iron pans, each 17 inches in diameter and 5 inches deep. A ½-inch pipe nipple was secured in the bottom of each pan near the side, the pan was supported at a height of about 1 foot above ground, and the nipple was inserted in the neck of a 1-gallon glass bottle. Under the major portions of the crowns of the trees there was complete leaf cover, but varying in thickness or density. The interceptometers were placed as nearly as possible under complete leaf-cover of average thickness.

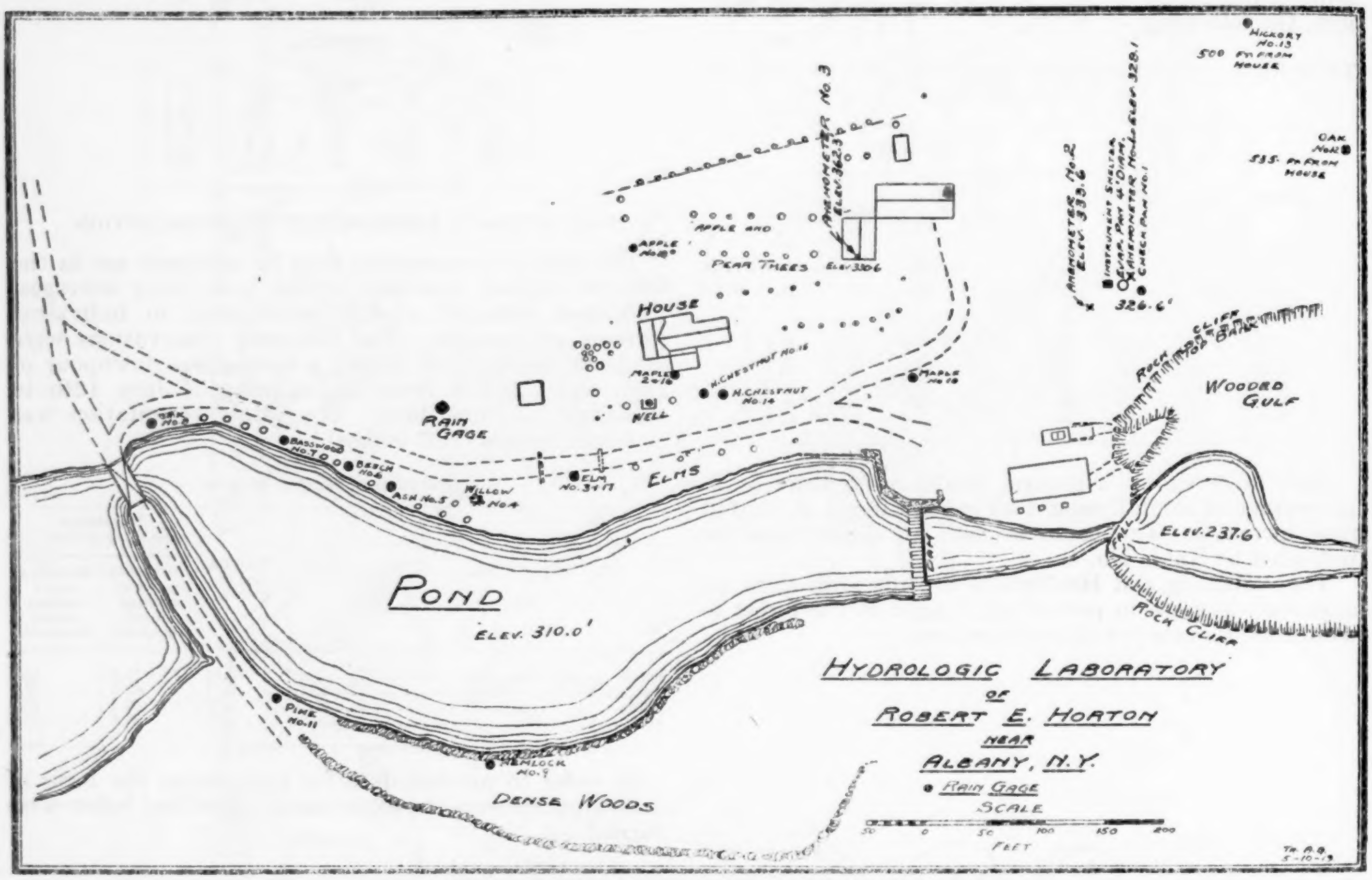


FIG. 3.—Map of author's hydrologic laboratory near Albany, N. Y.

Duplicate interceptometers were placed under maple, horse-chestnut, and elm trees, one in each case being near the trunk or about midway between the trunk and periphery of the tree, the other being just within the periphery. The peripheral interceptometers probably received direct rainfall rather than drippings from the tree, especially in the case of the elm, as the branches of this tree were 15 feet or more above ground, and the tree was in an exposed position, with the interceptometer on the south side, so that rains from the south or southwest falling at an angle with the wind could not be prevented from entering the gage directly.

In order to compare the catch by the interceptometers with that from an ordinary rain gage, a check interceptometer was maintained in the instrument inclosure alongside of a Friez tipping-bucket rain gage. This interceptometer gave readings practically identical in all cases with those obtained from the Friez rain gage.

A triangle of 3 rain gages was used, the rain gages being in the positions indicated on the map (fig. 3). There were nearly always slight differences in the amounts of rain caught by these gages, and in reducing the interceptometer results the rainfall on the tree crown has been taken as equal to that indicated by the mean of the three gages, although it is possible that a somewhat more accurate result might have been obtained by applying the results of a given rain gage to the records from trees to which the given rain gage stood nearest. The interceptometers were read in each instance as soon as practicable after the rain ceased, usually within an hour or two at most. Measurements were not, however, taken for each temporary cessation of rainfall. If, for example, two showers occurred separated by a rainless interval of not to exceed one hour, the rainfall for both showers was included in a single measurement.

The accompanying photographs, figures 4 to 9, inclusive, show several of the interceptometers and the trees in conjunction with them.

During the early part of 1917 the depths in the interceptometer bottles were measured with a rain-gage stick, the bottles having been previously calibrated by weighing. Later the water caught in the bottles has been measured in a calibrated can. The number of canfuls and the fraction of a canful, measured with a rain-gage stick, were recorded in each instance. The can was carefully calibrated for different depths by weighing on an accurate torsion balance. This method of measuring the water

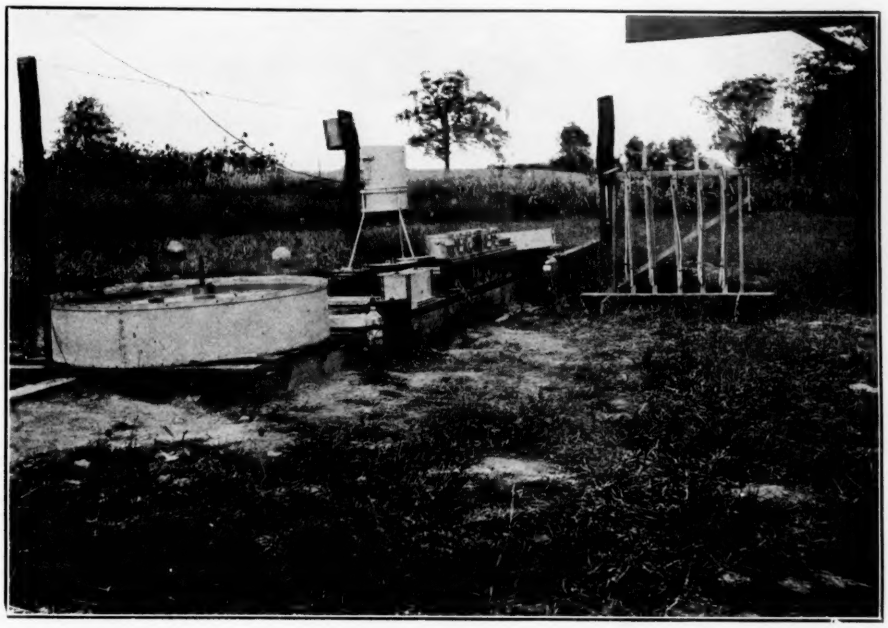


Fig. 4.—Evaporation station and check pan.

Fig. 5.—Interceptometer under hemlocks.

Fig. 6.—Interceptometer under willow shrubs.

FIG. 7.—Interceptometer under elm.

FIG. 8.—Interceptometer under elm, near view.

FIG. 9.—Interceptometer under ash, beech, and basswood.

caught in the tree-trunk tubs has been used throughout the work.

TABLE No. 6.—*Data for interceptometers.*

Pan No.	Tree.	Diameter of trunk.	Height.	Interceptometer to trunk C to C (A).	Interceptometer to periphery (B).[1]	Projected area.	Depth on area of 2 quarts =115.5 cubic inches.
		Feet.	*Feet.*	*Feet.*	*Feet.*	*Sq. ft.*	
1	Test gage						
2	Maple (house)	1.00		1½ sw	14	620	0.00130
3	Elm	1.95	55	8 se	13	1,240	.00065
4	Willow			1½ s	2	64	.01250
5	Ash	1.95		4½ n	18	1,320	.00061
6	Beech	.70		4½ ne	{7, 14}	200	.00401
7	Basswood	.75		8 n	{0, 7}	240	.00335
8	Oak	2.90	30	5 nw	14	625	.00128
9	Hemlock	1.40	42	5 se	9	350	.00229
10	Maple	.60	47	4 s	6½	285	.00282
11	Pine	2.10	65	4 n	13	1,035	.00078
12	Oak	2.40	65	12 sw	13	1,440	.00056
13	Hickory	1.45	50	6½ sw	11	950	.00085
14	Horse chestnut	1.90		13 ne	2½	780	.00103
15	....do	1.40		3 nw	12	435	.00185
16	Maple (house)	1.00		10.5 sw	5	620	.00130
17	Elm	1.95	55	12 s	9	1,240	.00065
18	Apple	1.85	30	5½ ne	13	845	.00095

[1] Where two values are given the greater one is to outside edge of foliage. Smaller one is to edge of foliage draining to trunk.

WATER RETURNED BY TREE TRUNKS.

In this study the data cited thus far relate to interception by tree crowns alone. In many instances, some portion of the intercepted water runs down the tree branches and trunk and so ultimately reaches the ground. The total interception loss by trees was determined by Riegler at Nancy by the use of gages of the same area as the tree crown, arrangements being made to include in the catch of the gage the part of the rainfall which flowed down the trunk. Riegler's experiments cited by Harrington have been reduced to percentages, and are presented in Table No. 7. These experiments also indicate the small differences in interception by various kinds of broad-leaved trees. The portion of the intercepted rainfall which reaches the ground by way of the tree trunk is apparently much smaller for evergreen than for broad-leaved trees. Zon states that the percentage of the total rainfall passing down the tree trunk varies from 0.7 of 1 per cent to 3 per cent for evergreens, and may be as high as 15 per cent for broad-leaved trees.

TABLE No. 7.—*Riegler's experiments on interception by trees.*

[Rain falling on tree crown=100 per cent.]

	Rain falling through crown on soil.	Rain running off trunk.	Total per cent reaching soil.	Loss per cent.
(1)	(2)	(3)	(4)	(5)
Beech	65.4	12.8	78.2	21.8
Oak	73.6	5.7	79.3	20.7
Maple	71.5	6.0	77.5	22.5
Spruce	39.8	1.4	41.2	58.8

NOTE.—Rain gage equal in area to tree crown. Results for spruce void, because part of rain ran off tips of outward inclined branches and was not caught by gage.—Harrington, Forest Influences, p. 133.

In order to determine the amount of water running down the trunks of trees, in the author's experiments, a small lead trough was constructed around each tree trunk, as shown on fig. 10. The troughs were made of lead flashing about one-sixteenth inch thick, cut into strips 2½ inches wide. The strip was first rolled while straight into approximately the form shown in the cross-section B, figure 10. The straight trough was filled with sand to preserve its form, and was wound around a prepared portion of the tree trunk, usually about 2 feet above ground. The tree trunk was prepared by removing rough scales and smoothing down the bark, care being taken not to make any deep incisions which would injure the tree. The trough was first tacked to the tree on the side opposite the pan, about midlength of the trough, then each end was carefully wound around to the opposite side in such a manner as to give the trough a slight inclination. The wider side of the trough which rested against the tree was nailed at various points with small nails, and the edge of the lead caulked as tightly as possible into all crevices and irregularities in the trunk.

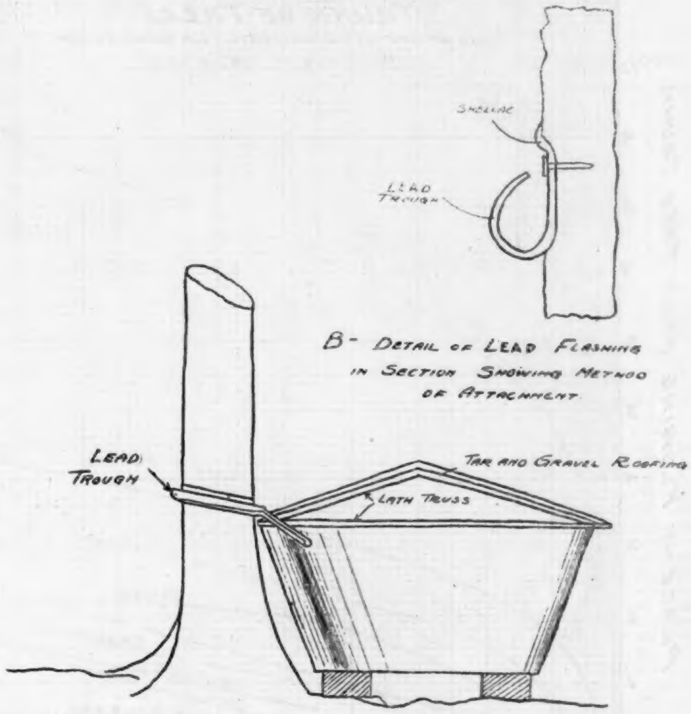


FIG. 10.—Typical tree-truck interceptometer with section of tub and cover.

The sand was then removed from the trough, the shorter end was bent over and into the longer projecting end of the trough, and the longer end was bent down so as to convey the water into the catch pan.

In 1917 melted paraffin was used to secure a water-tight joint between the upper edge of the lead and the bark of the tree. This would work well for a while, but afterwards would scale off, requiring frequent renewal to prevent leakage.

During 1918 several coats of thick shellac were used instead, with better results. The outside edge of the trough was bent over so as to leave an opening about one-fourth of an inch wide so as to prevent direct rainfall entering the trough in any considerable quantity. Covered 5-gallon galvanized pails were first used to catch the run-off, but it was found that for nearly all trees these would overflow, in a rain of a half inch or more, and large galvanized iron wash tubs were substituted, these tubs having a capacity of about 35 gallons each. Even then in some cases the tubs under certain trees would overflow during very heavy rains.

To prevent direct rainfall entering the tubs, and also to reduce evaporation, covers were made by constructing a light truss work of lath on which heavy tar and graveled roofing paper was tacked, thus providing a light, strong roof with inclination sufficient to carry the rain off readily, the roofing paper being lapped over the lead trough where the latter passed over the edge of the tub. The covers are held in position by weights and wires.

Early in the investigation it was found that there were surprisingly large variations in the amount of water caught in the tubs under different trees, and it soon became evident that smooth bark trees carry relatively large quantities of water down their trunks, while shag bark hickories, oaks, pines, and hemlocks permit but little water to pass down the trunks of the trees.

Since the trees stood in the open or in hedges they were more exposed than similar trees in a dense forest. In the case of a rain with driving wind, striking the exposed side of the tree, it is probable that a not inconsiderable portion of the water running down the trunks resulted from rain which struck the trunks directly, whereas, in the case of trees in dense forests this would not occur to any great extent. Close observation of the trees, and comparison of the results in rains which descended vertically and in strong winds indicate that this condition, while marked in some rains, does not usually prevail, and it may be safely assumed that nearly all the water running down the trunks would also have run down the trunks of trees in the forest. In nearly all cases, the water running down the tree trunks was of exceedingly dark color, that from pine and hemlock being nearly as black as molasses.

The volume of water caught from the trunk of a large smooth bark tree in a heavy shower was often 20 to 30 gallons. How this occurs is esily understood when one considers than a film 0.01 inch thick flowing down the trunk of a tree 3 feet in circumference at 10 feet per minute amounts to 216 cubic inches per hour. As the results subsequently given show, the water running down the tree trunks, when reduced to equivalent depth on the projected area of the tree crown, is relatively slight, as appears from Tables Nos. 8 and 9, which show the amounts of precipitation caught by the tree trunk interceptometers.

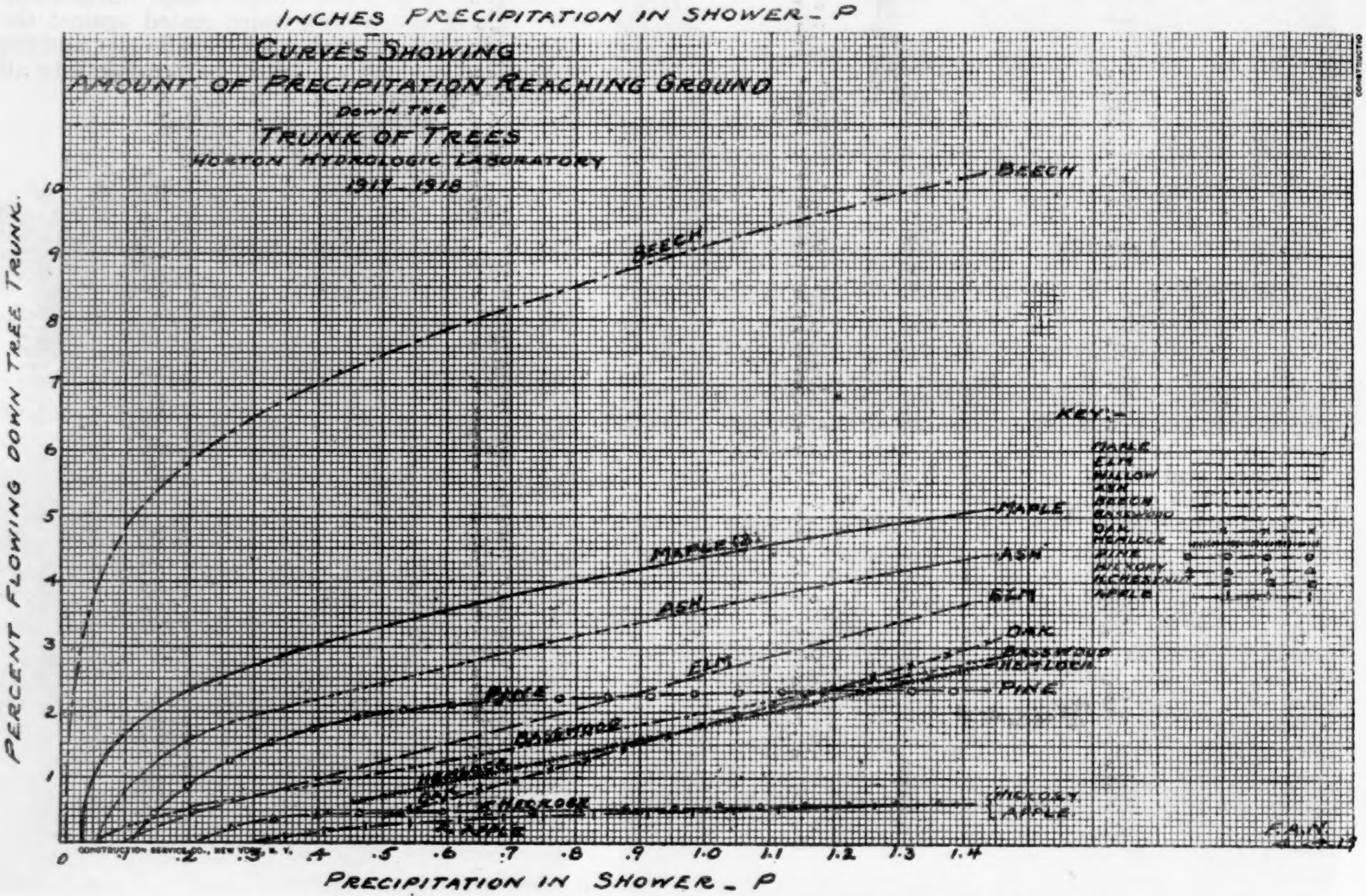


FIG. 11.—Summary of curves showing the amount of precipitation reaching ground down the tree trunks.

TABLE 8.—*Summary of amount of water in inches of precipitation flowing down trunk of tree for storms of various magnitudes.*

Number showers.	Kind of tree.	Precipitation (inches.)					
		0-0.05	0.05-0.10	0.10-0.30	0.30-0.60	0.60-1.0	1.0-2.0
2	Maple	T.	0.001	0.005	0.014	0.038	0.078
10	....do	T.	.001	.004	.010	.020	.053
3	Elm	T.	T.	.001	.004	.014	.042
17	....do						
4	Willow						
5	Ash	T.	T.	.003	.010	.017	.052
6	Beech	.001	.003	.011	.028	.064	.127
7	Basswood	T.	T.	.001	.003	.008	.032
8	Oak						
12	....do	T.	T.	T.	.001	.005	.033
9	Hemlock	T.	T.	.001	.002	.007	.030
11	Pine	T.	T.	.001	.008	.019	.027
13	Hickory	T.	T.	T.	.002	.004	.007
14	Horse-chestnut						
15	....do						
18	Apple	T.	T.	T.	.001	.003	.007

TABLE No. 9.—*Summary of amount of water in per cent of total precipitation per shower flowing down trunk of tree for storms of various magnitudes.*

Number showers.	Kind of tree.	Precipitation in shower (inches).					
		0-0.05	0.05-0.10	0.10-0.30	0.30-0.60	0.60-1.0	1.0-2.0
2	Maple	T.	1.5	2.7	3.3	5.2	6.1
10	.....do	T.	1.5	2.2	2.4	2.5	3.8
	Mean	T.	1.5	2.4	2.8	3.8	5.0
3	Elm	T.	T.	0.5	1.0	1.9	3.3
5	Ash	T.	T.	1.6	2.4	2.5	4.1
6	Beech	3.2	4.5	6.0	6.7	8.5	9.9
7	Basswood	T.	T.	0.6	0.7	1.3	2.5
12	Oak	T.	T.	T.	0.2	0.7	2.6
9	Hemlock	T.	T.	0.6	0.5	0.9	2.4
11	Pine	T.	T.	0.6	1.9	2.5	2.2
13	Hickory	T.	T.	T.	0 5	0.5	0.6
18	Apple	T.	T.	T.	0.2	0.4	0.6

Smoothed curves of these results are given on figure 11. In general the rough bark trunks conduct the least water to the ground, and in the case of apple, shag bark hickory, oak and hemlock very little rain runs down the trunks in showers of less than 0.2 to 0.3 inch. The curves are generally of parabolic form, showing a smaller percentage running down the tree trunks in light than in heavy showers.

TOTAL INTERCEPTION LOSS AS A PERCENTAGE OF THE PRECIPITATION PER SHOWER.

In working up the experimental records, data were tabulated in groups, each group including showers for which the precipitation fell between assigned limits. The group means for the different showers and interceptometers are contained in Table No. 10.

TABLE 10.—*Analysis of 1917–1918 interceptometer records.*

[Horton Hydrologic Laboratory, Voorheesville, N. Y.]

Tree.		Precipitation, 0-0.05.				Precipitation, 0.05-0.10.				Precipitation, 0.10-0.30.				Precipitation, 0.30-0.60.				Precipitation, 0.60-1.0.				Precipitation, 1.0-2.0.			
No.	Kind of tree.	Number of showers.	Amount of precipitation.	Duration of rain.	Loss.	Number of showers.	Amount of precipitation.	Duration of rain.	Loss.	Number of showers.	Amount of precipitation.	Duration of rain.	Loss.	Number of showers.	Amount of precipitation.	Duration of rain.	Loss.	Number of showers.	Amount of precipitation.	Duration of rain.	Loss.	Number of showers.	Amount of precipitation.	Duration of rain.	Loss.
			In.	Hrs.	In.		In.	Hrs.	In.		In.	Hrs.	In.		In.	Hrs.	In.		In.	Hrs.	In.		In.	Hrs.	In.
2	Maple	12	0.031	0.71	0.026	18	0.067	1.18	0.012	31	0.18[illegible]	2.18	0.063	17	0.418	3.63	0.123	5	0.724	6.31	0.170	2	1.278	8.70	0.262
10	.....do	5	.034	1.13	.027	12	.065	1.27	.014	20	.185	2.40	.093	12	.416	4.11	.188	3	.806	8.06	.421	2	1.410	5.12	.504
16	.....do.[1]	3	.013	1.15	.018	12	.065	1.27	.035	17	.187	2.33	.057	12	.416	4.11	[2]—.016	5	.725	6.31	.095	1	1.257	10.91	.735
	Mean	......	.036	1.00	.024	......	.066	1.24	.010	......	.185	2.30	.071	......	.417	3.95	.098	......	.752	6.80	.230	......	1.315	8.24	.500
3	Elm	12	.031	0.71	.025	18	.067	1.18	.053	31	.18[illegible]	2.18	.083	17	.418	3.63	.139	5	.724	6.31	.189	1	1.257	10.91	.187
17	.....do.[1]	2	.013	0.24	.018	12	.065	1.27	.039	18	.192	2.28	.066	11	.417	4.43	.070	4	.755	6.71	.074	......	......	......	......
	Mean	......	.037	0.48	.022	......	.066	1.22	.0[illegible]6	......	.188	2.23	.075	......	.418	4.03	.104	......	.740	6.51	.131	......	1.257	10.91	.187
4	Willow [3]	12	.031	0.71	.024	18	.067	1.18	.0[illegible]6	31	.184	2.18	.087	17	.418	3.63	.172	5	.724	6.31	.367	2	1.278	8.70	.564
5	Ash	12	.031	0.71	.011	18	.067	1.18	.028	31	.18[illegible]	2.18	.019	17	.418	3.63	[2].105	4	.694	5.57	.262	2	1.278	8.70	.268
6	Beech	12	.031	0.71	.023	18	.067	1.18	.035	31	.18[illegible]	2.18	.061	17	.418	3.63	.130	4	.755	7.21	.121	2	1.278	8.70	.316
7	Basswood [3]	9	.027	0.52	.022	6	.070	0.98	.035	13	.173	2.07	[2].016	5	.42	2.51	[2]—.005	1	.603	4.68	.215	1	1.257	10.91	[2]—.028
8	Oak [3]	9	.027	0.52	0.25	6	.070	0.98	.053	13	.173	2.07	.073	5	.42	2.51	.177	1	.603	4.68	.319	1	1.257	10.91	.340
12	.....do	5	.034	1.13	[2].002	12	.065	1.27	.042	20	.185	2.40	.051	12	.416	4.11	.050	4	.755	7.22	.121	1	1.257	10.91	.396
	Mean	......	.030	0.82	.014	......	.068	1.12	.018	......	.179	2.23	......	......	.420	3.31	.113	......	.679	5.95	.220	......	1.257	10.91	.368
9	Hemlock	11	.032	0.67	.022	18	.067	1.18	.056	28	.180	2.22	.088	16	.417	3.79	.105	4	.755	7.21	.188	1	1.257	10.91	.489
11	Pine	11	.032	0.67	.023	18	.067	1.18	.055	28	.180	2.22	.089	16	.417	3.79	.151	4	.755	7.22	.114	1	1.257	10.91	.026
13	Hickory	5	.034	1.13	[2].003	11	.066	1.32	.018	20	.185	2.40	[2].041	12	.416	4.11	[2]—.0[illegible]0	4	.755	7.22	[2].059	1	1.257	10.91	[2]—.125
14	Horsechestnut [1,3]	5	.034	1.13	.022	12	.065	1.27	.013	20	.185	2.40	[2].058	12	.416	4.11	.111	5	.725	6.31	.083	1	1.300	6.50	.345
15	.....do.[3]	5	.034	1.13	.024	12	.065	1.27	.041	20	.185	2.40	.088	12	.416	4.11	.160	5	.725	6.31	.270	1	1.300	6.50	.493
	Mean	......	.034	1.13	.023	......	.065	1.27	.012	......	.185	2.40	.073	......	.416	4.11	.135	......	.725	6.31	.176	......	1.300	6.50	.419
18	Apple	5	.034	1.13	.018	12	.065	1.27	.041	20	.185	2.40	.076	12	.416	4.10	.106	4	.755	7.22	.176	1	1.257	10.91	.349
	Mean of all	......	.033	0.83	.020	......	.066	1.20	.043	......	.183	2.26	.067	......	.418	3.76	.102	......	.726	6.52	.191	......	1.277	9.44	.320
	Mean of all except Nos. 4, 7, 8, 14, and 15	......	.034	0.84	.018	......	.066	1.23	.043	......	.185	2.28	.068	......	.417	3.92	.093	......	.746	6.88	.166	......	1.277	9.78	.310
	Mean of all except Nos. 14, 16, and 17	......	.032	0.83	.020	......	.067	1.19	.044	......	.182	2.25	.068	......	.417	3.66	.111	......	.724	6.54	.214	......	1.277	9.55	.289

[1] Near periphery of tree cover.
[2] Mean is low due to few large negative results.
[3] Trees for which trunk water was not collected and for which correction has been made.

Table No. 11 shows the same results, in condensed form, and reduced to the basis of percentages of the total precipitation per shower which was lost or intercepted, corrected for rain running down the tree trunks. The average loss ranges from 70 per cent of the total in very slight showers, to about 24 per cent in heavy, long-continued rains

TABLE No. 11.—*Summary of interceptometer records showing amount of water lost to ground by tree interception.*

Tree.		Percentage of precipitation lost.					
No.	Kind of tree.	0-0.05	0.05-0.10	0.10-0.30	0.30-0.60	0.60-1.0	1.0-2.0
2	Maple	83.8	62.7	34.2	29.4	23.5	20.5
10	.....do	79.4	67.7	50.3	45.2	52.6	35.7
16	.....do.[1]	41.8	54.0	30.5	([2])	13.1	58.5
	Mean Nos. 2 and 10	81.6	65.2	42.2	37.3	38.0	28.1
3	Elm	80.6	79.1	45.1	33.3	26.1	14.9
17	.....do.[1]	41.8	60.0	34.4	16.8	9.8	....
	Mean	61.2	69.6	39.8	25.0	18.0	14.9
4	Willow[3]	77.4	68.7	47.3	41.1	50.6	44.1
5	Ash	35.5	41.8	26.6	[2] 25.1	37.7	21.0
6	Beech	74.2	52.2	33.1	31.1	16.0	24.7
7	Basswood[3]	81.5	50.0	([2])	([2])	35.6	([2])
8	Oak[3]	92.5	75.7	42.2	41.8	52.8	27.1
12	.....do.[3]	([2])	64.7	27.6	12.0	16.0	31.5
	Mean[3]	....	70.2	34.9	26.9	34.4	29.8
9	Hemlock	68.7	83.6	48.9	25.2	24.9	38.9
11	Pine	71.9	82.1	49.5	36.2	15.1	2.1
13	Hickory	([2])	72.7	[2] 22.2	([2])	[2] 7.8	([2])
14	Horse chestnut[1, 3]	64.7	66.2	[2] 31.4	26.7	11.4	26.5
15	.....do.[3]	70.5	63.1	47.6	38.5	37.2	37.9
	Mean[3]	67.6	64.6	39.5	32.6	24.3	32.2
18	Apple	52.9	63.1	41.1	25.5	23.3	27.8
	Mean of all	70.5	65.1	38.2	39.5	26.7	29.4
	Mean of all except 4, 7, 8, 14, 15, 16, 17	68.4	67.0	37.6	29.6	24.6	24.3

[1] Near periphery of tree cover.
[2] Percentage too small: Too many negative results involved in one mean.
[3] Not corrected for water running down the trunk; all others are corrected.

Figure 12 shows the percentage loss for all trees, on a comparative basis. In general, with regard to all the curves, the plotted points are very consistent for smaller amounts of rainfall where the number of observations included in a group mean was relatively large. There were several showers of less than 0.05 inch rain, in which nothing was caught in the interceptometers, and which showers were not included in making out the group means. The effect of including these would be to make the percentage interception for rainfall amounts of less than 0.05 inch somewhat larger. The low loss for heavy showers in the case of the hickory and elm, especially the former, is undoubtedly due to the exposure of the trees and the height of the crown above ground. As a result of these conditions, the interceptometers received direct precipitation in some showers, accompanied by wind blowing from the same side of the trees as that on which the interceptometer was placed. The curves are in general hyperbolic in form, and could be expressed by formulae of the type

$$\text{Per cent loss} = a + \frac{b}{P}$$

in which a and b are constants, and P is the amount of precipitation per shower. Here a represents interception storage depth, and $a+b$ is the ordinate of the asymptotic line, which the curve approaches as the amount of precipitation increases indefinitely. In other words, the interception loss approaches a constant percentage of the total precipitation in very heavy rains.

Figure 13 is an average of all the curves, expressed in a similar manner.

INTERCEPTION DEPTH ON PROJECTED TREE-CROWN AREA PER SHOWER.

In figure 14, the results are shown graphically in terms of the amount of precipitation loss over the projected area of the crown of the tree.

Figure 15 is the mean of the curves shown on figure 14. This is a straight line, except near the origin, and would be apparently a straight line throughout but for the fact that in very light showers, less than sufficient to satisfy the interception storage, some of the rain may be shaken off the trees by the wind.

The amount of interception storage for each tree is approximately determined by extending the line or curve on figure 14 to the zero precipitation line, in the direction determined by the portion of the curve plotted for rains exceeding the interception storage. For rains less in amount than the average interception storage, the interception loss would be in general 100 per cent, if there were no wind, but may be less, if a portion of the storage remaining on the tree at the end of the shower is shaken off by the wind.

The accompanying formulæ show the average interception, corrected for water running down the trunks of the trees, expressed in terms of precipitation per shower. In the linear formulæ the first constant represents the interception storage and the second the limiting minimum proportion of the rain lost as the amount per shower increases.

Summer season interception per shower by various trees.

$J=0.015+0.23\ P_s$ .... Ash.
$J=0.04+0.18\ P_s$ .... Apple.
$J=0.04+0.20\ P_s$ .... Horse-chestnut.
$J=0.02+0.23\ P_s$ .... Beech.[1]
$J=0.03+0.22\ P_s$ .... Oak (mean).
$J=0.03+0.23\ P_s$ .... Maple.
$J=0.23\ P_s^{1/2}$ .... Elm (No. 3).[2]
$J=0.13\ P_s^{1/2}$ .... Basswood.
$J=0.20\ P_s^{1/2}$ .... Hemlock and pine.
$J=0.02+0.40\ P_s$ .... Willow shrubs.[3]

The formulas apply only when P is greater than the constant, otherwise $J=P$, nearly.

In deriving these formulæ, results obtained by peripheral interceptometers have been disregarded for reasons elsewhere stated. It will be noted by reference to figure 12 that the interception loss for oak, maple, ash, beech, and horse-chestnut are very nearly the same, and an average formula for these trees may be used. In the case of all except the hemlock, pine, and elm trees, the interception curves either in terms of precipitation per shower, or shower duration are straight lines. In the case of the hemlock, pine, and elm, the curves both in terms of amount and duration are parabolic in form. In the case of the pine and hemlock, the bark and leaves seem to absorb a relatively large amount of precipitation as hygroscopic moisture.

The relatively large loss by interception from willows, which in this case were shrubs of 8 to 10 feet in height, is notable. This loss greatly exceeds that for other trees, except the basswood, even after correction for water running down the trunks, which correction in the case of the willow shrubs was estimated from the data for other trees.

The following Table No. 12 shows the mean precipitation in each shower and the mean loss per shower for each kind of tree.

The inaccuracy of using average percentages in calculating interception losses in individual cases is illustrated by the following example. The average precipitation per shower during the 78 experiments on pine was 0.22 inch, and the average interception loss from the

[1] Tree crown partly defoliated.
[2] Apparently deficient for storage, because of high crown and direct catch of rain.
[3] Probably excessive, apparently much water runs down stem.

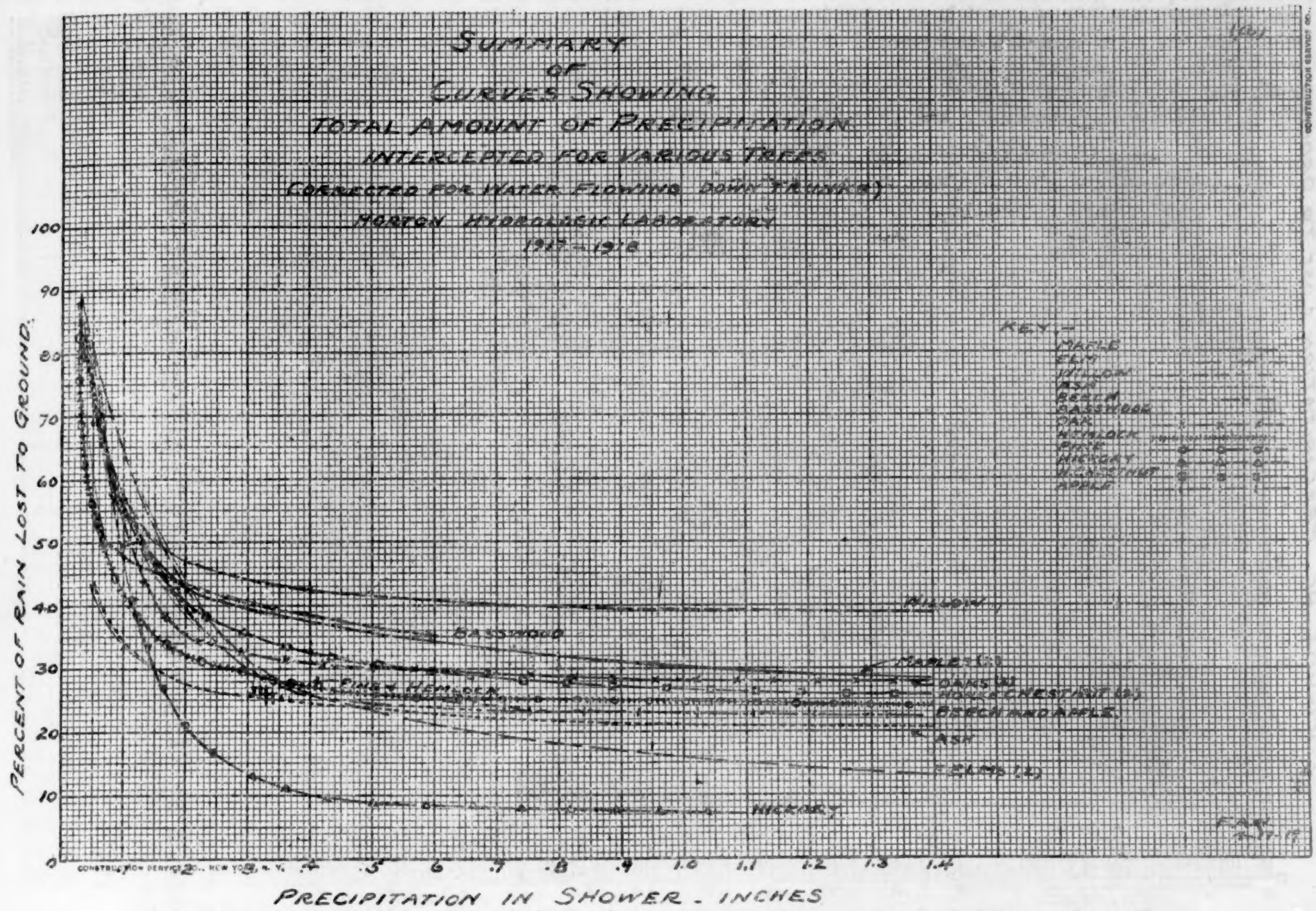


FIG. 12.—Summary of curves showing total amount of precipitation intercepted for various trees. (Corrected for water flowing down trunks.)

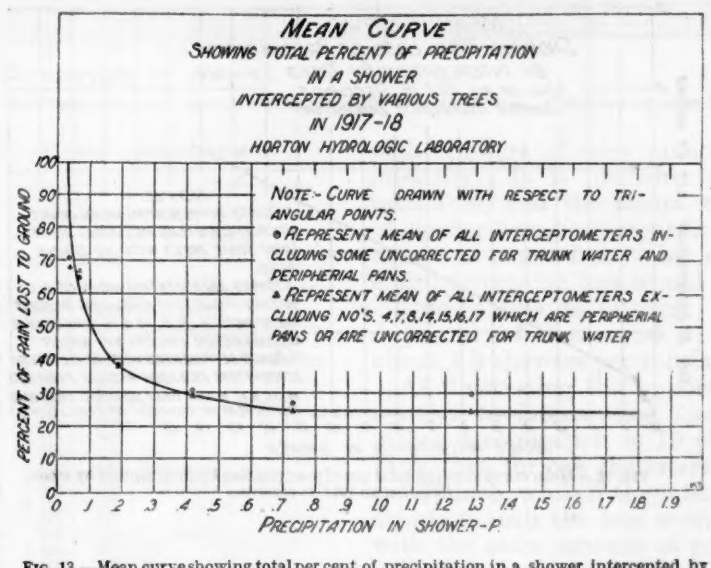


FIG. 13.—Mean curve showing total per cent of precipitation in a shower intercepted by various trees in 1917–18.

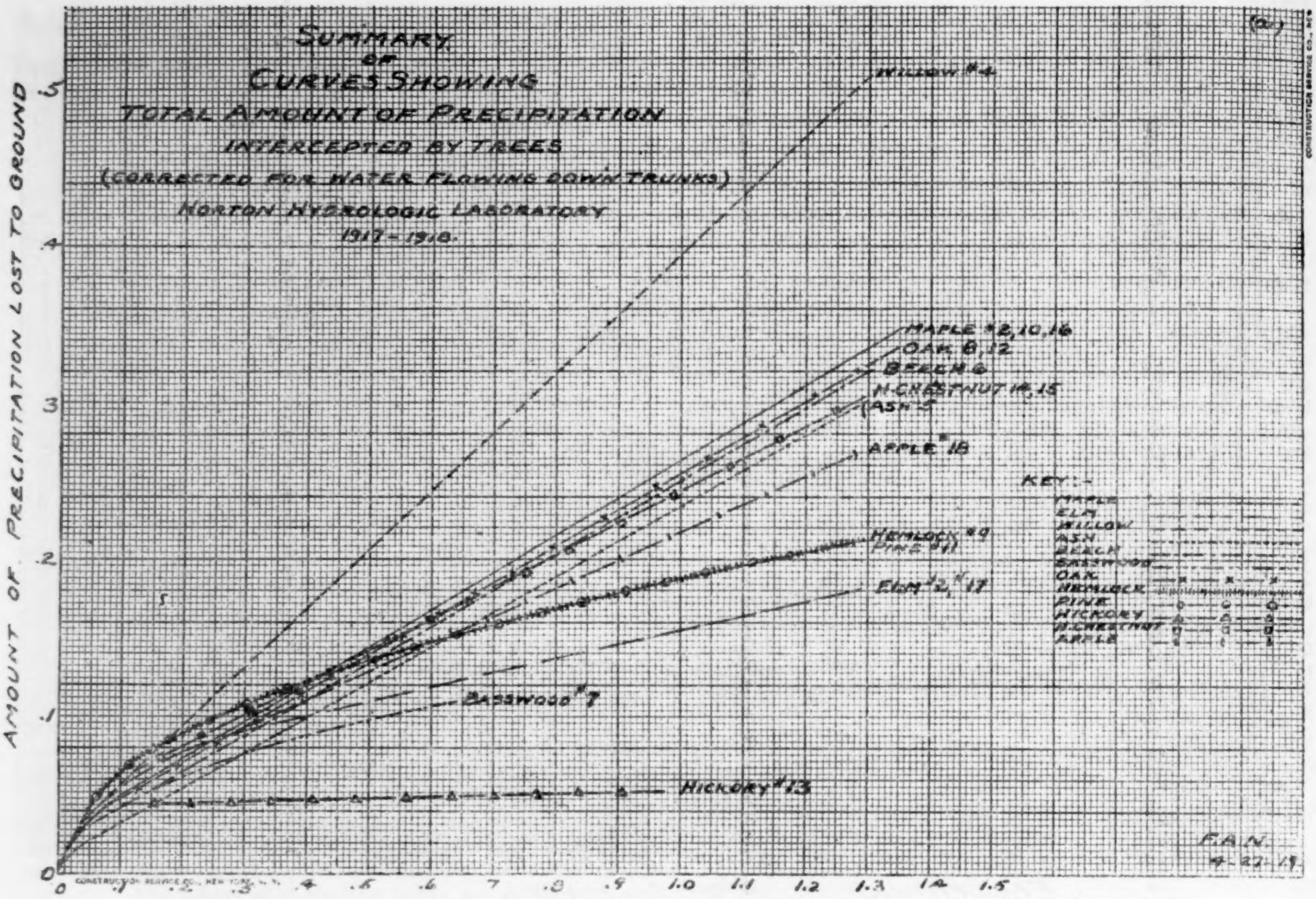


FIG. 14.—Summary of curves showing total amount of precipitation **intercepted by trees.** **(Corrected for water flowing down trunks.)**

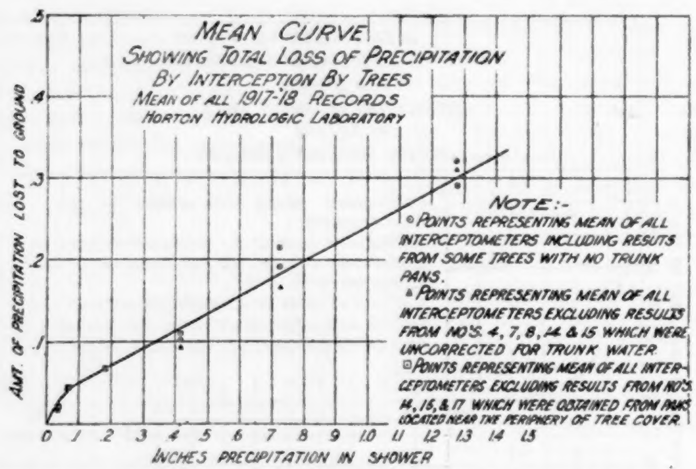


FIG. 15.—Mean curve showing total loss of precipitation by interception by **trees.**
(Mean of all 1917-18 records.)

pine tree was 0.085 inch per shower, or 38.7 per cent. Consider a month with 5 inches precipitation—based on the average percentage there would be a total loss of 1.935 inches. If, for example, the precipitation during the given month consisted of 50 showers of 0.10 inch, the loss would be 3.15 inches, while if the rain had fallen in 5 showers of 1 inch each the loss would have been only 0.915 inch.

INTERCEPTION LOSS IN TERMS OF SHOWER DURATION.

Figure 16 contains curves showing the precipitation loss expressed in terms of duration of the shower in hours.

It should be noted that the data were not tabulated directly in terms of shower duration. The method of deriving the group means sometimes includes showers of short duration and high intensity in the same group

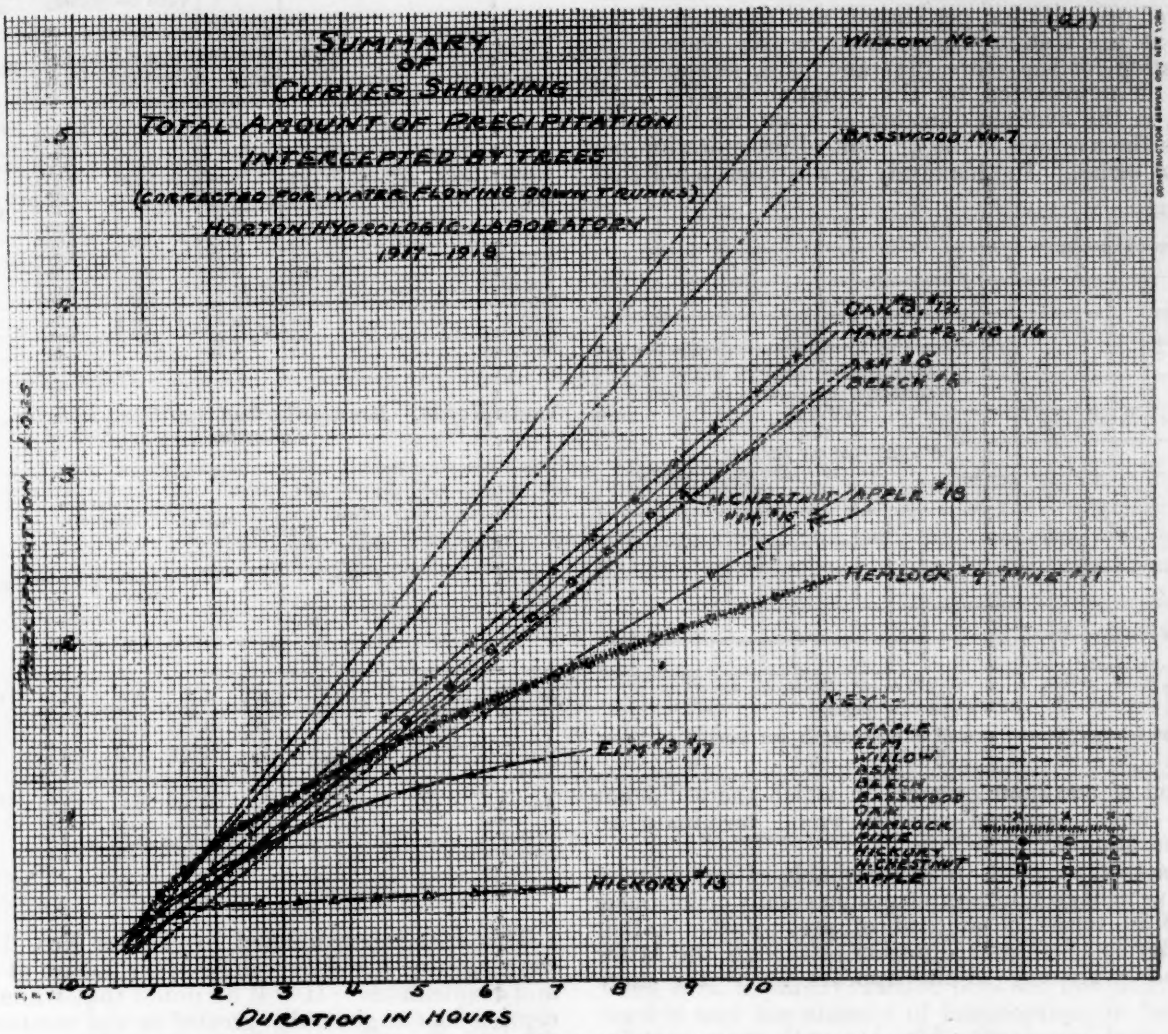


FIG. 16.—Summary of curves showing total amount of precipitation intercepted by trees. (Corrected for water flowing down trunks.)

TABLE 12.—*Average results, 1917–18, interceptometer records.*

Tree. No.	Tree. Kind of tree.	Number of showers.	Precipitation (inches). Total.	Precipitation (inches). Mean.	Loss (inches). Total.	Loss (inches). Mean.	Notes.
2	Maple	85	17.152	.200	6.454	*.076	Near trunk.
10	.....do	54	14.880	.290	7.059	.131	Under group of small trees with undergrowth.
16	.....do	50	13.962	.279	2.461	.049	Same as Z but near edge.[1]
3	Elm	84	19.265	.229	7.325	.087	
17	.....do	47	11.929	.254	2.758	.059	
4	Willow	85	20.564	.242	9.700	.114	([1]).
5	Ash	84	19.720	.235	5.524	.066	
6	Beech	84	19.922	.237	5.435	.065	
7	Basswood	35	6.892	.197	.778	.022	([1]).
8	Oak	35	6.892	.197	3.036	.087	1917 only.[1]
12	.....do	54	13.919	.258	3.014	.056	1918 only.
9	Hemlock	78	17.547	.225	6.635	.085	
11	Pine	78	17.547	.225	6.633	.085	
13	Hickory	53	13.865	.262	.994	.019	Do.
14	Horse chestnut	55	14.567	.265	3.878	.071	([1]).
15	.....do	55	14.567	.265	6.135	.112	([1]).
18	Apple	54	13.919	.258	4.427	.082	1918 only.

[1] No trunk interceptometer used.

with showers of very much longer duration but lower intensity. It is probable that if the data had been tabulated, and the means taken for groups of showers of similar duration, regardless of the amount of precipitation, a somewhat closer correlation between showers and interception loss would have resulted.

During July to October, 1917, there were 42 rainfall days and 54 showers of .01 inch or more, an average of about 1.3 showers per rainfall day.

As illustrating the importance of rainfall duration in relation to interception loss, consider a month with 2 inches precipitation in 10 showers of 2 hours' duration each, then for oak the interception loss would be $10 \times .07 = 0.70$ inch, while if there had been 4 showers of 2 hours' duration each the loss would have been only 0.28 inch, with the same amount of precipitation for the month.

During April to October, 1918, there were 70 rainfall days, with 130 showers of 0.01 inch or more, an average of 1.88 showers per rainfall day.

If we consider the interception in each shower as at least equal to the interception storage, then as an approximation, 1.5 showers per rainfall day may be considered as a fair average, as this will represent the approximate number of showers per day with 0.01 inch or more of rain, the interception in showers of less than 0.01 inch being about sufficient to make up the deficiency in interception storage for showers of 0.02 to 0.03 inch.

There is in general a fairly close relation between the amount of precipitation per shower and duration of the shower, at the station where these records were kept. This relation for the years 1917 and 1918, as shown by Fig. 17, is represented by the equation $h_s = 7.4\ P_s^{0.70}$ where h_s is the average duration of a shower in hours, and P_s is the average of the amount of precipitation per shower in inches. In this study it was considered that

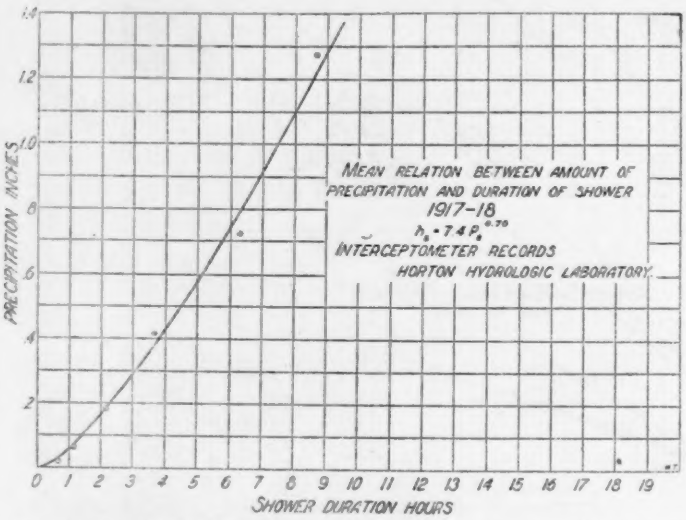


FIG. 17.—Mean relation between amount of precipitation and duration of shower, 1917-18.

any period of one hour or more in which there did not fall 0.01 inch measured rainfall would terminate an antecedent shower.

For practical purposes, it will probably often be found more convenient to utilize interception results or formulae expressed in terms of amount of precipitation rather than in terms of shower duration, although the latter method of expressing results appears to be the more logical.

RELATION OF INTERCEPTION TO EVAPORATION.

Since interception losses are in reality evaporation losses, it might naturally be expected that there would be a fairly close relation between the relative amount of interception losses in different months of the year, and the relative evaporation in the same months. The data available previous to the experiments of the author do not show any consistent relation of this kind.

TABLE NO. 13.—*Monthly distribution of interception losses, Adlisburg Switzerland, 1889-90.*

Month.	Number rainfall days.	Precipitation in the open.	Total loss (inches).		Loss per rainfall day (inches).	
			Under beech.	Under fir.	Beech.	Fir.
(1)	(2)	(3)	(4)	(5)	(6)	(7)
January	17	2.68	....	0.93	....	0.055
February	26	3.71	....	1.84	....	.071
March	25	3.29	0.30	2.09	0.012	.084
April	32	6.00	.73	3.10	.023	.097
May	15	3.39	.043	1.75	.003	.117
June	43	9.85	....	4.52	....	.105
July	35	9.33	1.18	2.39	.034	.068
August	40	14.90	.75	3.07	.019	.077
September	16	5.29	.28	.77	.017	.048
October	34	9.90	1.38	1.74	.041	.051
November	36	4.72	.30	1.86	.008	.052
December	15	1.34	....	.64	....	.043

TABLE NO. 14.—*Monthly distribution of interception loss, Haidenhaus, Switzerland, 1890.*

Month.	Mean air temperature (° F.).	Number rainfall days.	Precipitation in the open.	Total loss (inches).		Loss per rainfall day (inches).	
				Under beech.	Under fir.	Beech.	Fir.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
January	23.2	15	3.36	0.76	1.53	0.051	0.102
February	24.8	5	.20	.008	.16	.0016	.032
March	29.9	11	1.16	.15	.51	.014	.046
April	39.4	19	3.02	.60	1.40	.032	.074
May	53.96	15	4.86	1.45	2.13	.097	.142
June	59.9	19	2.65	1.02	1.51	.054	.079
July	59.9	21	4.72	1.40	2.57	.067	.122
August	57.6	21	9.30	2.13	3.90	.101	.186
September	49.1	6	1.55	.46	.66	.077	.110
October	42.3	15	5.36	1.56	2.00	.104	.133
November	33.8	23	2.51	.70	1.92	.030	.084
December	27.7	4	.33	....	.075	....	.019

This fact is exemplified by Tables Nos. 13 and 14, showing the monthly interception losses at Adlisberg and Haidenhaus. It will be noted that while the interception loss is generally greater in the summer months, May to October, inclusive, than in the winter, the monthly results do not show any very consistent relation to the average evaporation curve, which, as well known, increases from May until about August 1, and then decreases.

TABLE No. 15.—*Monthly summary, rainfall caught in interception pans, inches, Horton hydrologic laboratory.*

Month.	Evaporation (inches)	Precipitation.			Check pan No. 1.	Maple (house), No. 2.		Elm, No. 3.		Willow, No. 4.		Ash,[1] No. 5.		Beech, No. 6.		Basswood, No. 7.		Oak, No. 8.	
		No. 1, T. B.	No. 2, Erwin's.	No. 3, field.		Pan.	Trunk.	Pan.	Trunk.	Pan.	Trunk.	Pan.	Trunk.	Pan.	Trunk.	Pan.	Trunk.	Pan.	Trunk.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
1917.																			
August	5.41	2.45	2.36	2.19	2.423	1.430	0.044	1.132	0.006	1.008	......	1.842	0.024	1.602	0.107	2.156	0.015	1.243	......
September	3.72	1.54	1.38	1.51	1.282	.665	.035	.671	.012	.588	......	1.143	.022	1.046	.079	1.528	.013	.954	......
October	1.61	3.66	3.46	4.10	2.748	2.528	.245	2.999	.093	2.329	......	3.180	.157	2.658	.387	3.029	.074	2.344	......
1918.																			
May	5.280	2.86	2.73	2.92	2.616	1.866	.118	1.818	.029	1.772	......	2.164	.094	1.666	.266	......	......	......	......
June	5.056	2.15	2.08	2.30	2.093	1.288	.066	1.272	.017	1.022	......	1.262	.050	1.206	.165	......	......	......	......
July	5.931	1.56	1.63	1.72	1.587	1.060	.034	.857	.007	.820	......	1.241	.032	.996	.075	......	......	......	......
August [2]	5.921	1.65	1.55	1.62	1.577	1.038	.035	1.049	.010	.800	......	1.013	.042	.906	.104	......	......	......	......
September	2.749	4.33	4.27	4.65	4.015	2.598	.199	1.608	.061	2.875	......	1.673	.063	2.440	.287	......	......	......	......
October	2.212	1.68	1.67	1.78	1.647	1.225	.112	1.107	.118	1.272	......	1.072	.045	.920	.140	......	......	......	......
Mean for 1918	4.525	2.37	2.32	2.50	2.256	1.513	.094	1.325	.040	1.427	......	1.404	.054	1.356	.173	......	......	......	......
1919.																			
April	2.486	2.26	2.19	2.43	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
May	4.514	4.41	4.41	4.84	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
June	5.289	1.68	1.61	1.74	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
July	6.275	3.58	3.48	3.70	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......

Month.	Hemlock, No. 9.		Maple (bank), No. 10.		White pine, No. 11.		Oak (east), No. 12.		Hickory, No. 13.		Horse chestnut, No. 14.		Horse chestnut (west), No. 15.		Mapel (house), No. 16.		Elm, No. 17.		Apple, No. 18.	
	Pan.	Trunk.	Pan.	Trunk.	Pan.	Trunk.	Pan.	Trunk.	Pan.	Trunk.	Pan.	Trunk.	Pan.	Trunk.	Pan.	Trunk.	Pan.	Trunk.	Pan.	Trunk.
(1)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)	(33)	(34)	(35)	(36)	(37)	(38)	(39)	(40)
1917.																				
August	1.424	......	......	......	1.119	0.003	......	......	......	......	......	......	......	......	......	......	......	......	......	......
September	1.037	......	......	......	1.050	.003	......	......	......	......	......	......	......	......	......	......	......	......	......	......
October	2.655	0.062	1.807	0.136	3.197	.051	3.177	0.037	3.978	0.014	3.526	......	3.134	......	......	......	3.530	0.093	2.754	0.023
1918.																				
May	1.970	.022	1.471	.067	1.414	.048	2.387	.009	2.703	.009	2.041	......	1.761	......	2.423	......	2.095	......	1.870	.006
June	1.512	.006	.978	.039	1.560	.047	1.794	.005	2.146	.006	1.515	......	1.174	......	1.852	......	1.424	......	1.562	.004
July	.725	.004	.718	.019	1.059	.004	1.104	.001	1.344	.005	1.206	......	.769	......	1.060	......	1.125	......	1.062	.000
August [2]	1.211	.006	1.052	.025	.999	.039	1.475	.017	1.826	.014	1.328	......	.836	......	1.485	......	1.337	......	1.332	.012
September	1.461	.013	2.749	.196	1.542	.064	1.968	.036	2.674	.022	3.060	......	2.312	......	2.009	......	1.916	......	1.922	.031
October	.810	.000	.890	.060	.670	.022	1.317	.000	1.473	.005	1.048	......	1.109	......	1.454	......	1.270	......	1.118	.002
Mean for 1918	1.281	.008	1.377	.068	1.207	.037	1.674	.011	2.028	.010	1.700	......	1.337	......	1.714	......	1.528	......	1.478	.009

[1] About one-half leaves stripped by caterpillars in 1917.

[2] Not monthly total; 2 days (25 and 29) excluded.

TABLE No. 16.—*Monthly summary, rainfall losses by interception. May–October, inclusive, 1918, Horton hydrologic laboratory.*

	Pan number.	Monthly losses (inches).						Total.	Mean.	Mean loss in per cent of rainfall.
		May.	June.	July.	August.[1]	September.	October.			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Evaporation	....	5.280	5.056	5.931	5.921	2.749	2.212	27.149	4.525	.....
Precipitation	....	2.837	2.177	1.637	1.610	4.412	1.700	14.373	2.396	.....
Check pan	1	2.616	2.093	1.587	1.577	4.015	1.647	13.535	2.256	.....
Maple (house)[2]	2	.853	.823	.543	.537	1.615	.363	4.734	.789	33.0
Elm	3	.990	.888	.773	.551	2.743	.475	6.420	1.070	44.7
Willow [3]	4	1.065	1.155	.817	.810	1.537	.428	5.812	.969	40.4
Ash	5	.579	.865	.364	.555	2.676	.583	5.622	.937	39.1
Beech	6	.905	.806	.566	.600	1.685	.640	5.202	.867	36.2
Hemlock	9	.845	.659	.908	.393	2.938	.890	6.633	1.106	46.2
Maple (bank)[4]	10	1.299	1.160	.900	.533	1.467	.750	6.109	1.018	42.5
White pine	11	1.375	.570	.574	.572	2.806	1.008	6.905	1.151	48.1
Oak (east)	12	.441	.378	.532	.118	2.408	.383	4.260	.710	29.6
Hickory	13	.125	.025	.288	......	1.716	.222	2.376	.475	19.8
Horse chestnut [3, 5]	14	.796	.662	.431	.282	1.352	.652	4.175	.696	29.1
Horse chestnut (west)[3, 6]	15	1.076	1.003	.868	.714	2.100	.591	6.352	1.059	44.2
Maple (house)[3, 5]	16	.414	.325	.577	.125	2.403	.246	4.090	.682	28.5
Elm [3, 5]	17	.742	.753	.512	.273	2.496	.430	5.206	.868	36.2
Apple	18	.961	.611	.575	.264	2.459	.580	5.450	.908	37.9

[1] Two days (25 and 29) excluded; values are not monthly totals.
[2] Near trunk.
[3] Without trunk interception.
[4] Under group of small trees with undergrowth.
[5] Near edge.
[6] Near trunk with undergrowth.

NOTE.—2 and 16 and 3 and 17 under same tree.

Table 15 shows the results of the author's experiments, expressed in terms of the monthly amount of precipitation caught in each interceptometer, and Table No. 16 shows the monthly interception losses. Here again there is no apparent relation between the monthly evaporation and the amount of interception, in fact if such relation exists, it would evidently require long statistical records in order that it might be revealed by data analyzed on the monthly basis.

As a further test to reveal whether the experiments indicate the existence of a close correlation between interception loss and evaporation loss, the data for showers of 0.1 to 0.3 inch precipitation were analyzed, as shown in Table No. 17. This method of analysis should eliminate some of the uncertainties of the presentation of data in the form given in Tables Nos. 13, 14, and 16, inasmuch as only results for showers of about equal intensity are compared in Table No. 17. Here, however, there is, as before, no consistent relation between evaporation rate and interception loss. Apparently this relation, although it probably exists, is not very marked. One of the principal reasons is apparently the fact that rainfall duration is generally much greater in the autumn, winter, and spring than during the midsummer months. Interception loss is proportional to evaporation rate and rainfall duration. It so happens that during the months when the evaporation is the greatest the rainfall duration is

the least, and vice versa. As a result, the interception losses are more nearly constant than the evaporation rate.

Until more detailed studies have been made, it appears that for practical purposes interception formulæ deduced for summer conditions may be applied throughout any of the months May to October, inclusive, without sensible error.

As regards watershed effect, somewhat better results might be obtained by placing peripheral interceptometers immediately underneath the marginal leaves of the tree, instead of on the ground.

In order to test further the effect of different exposures of interceptometers under the same tree crown, a series of six interceptometers was placed under each of the

TABLE No. 17.—*Monthly means of rainfall interception for showers of 0.10 to 0.30 inch, Horton hydrologic laboratory, 1917–18.*

Month.	Mean precipitation per shower.	Mean shower duration (hours).	Evaporation (inches).[1]	Net loss, inches per month.														
				Maple.			Ash No. 5	Beech No. 6	Willow No. 4.[2]	Oak Nos. 8 and 12.	Hemlock, No. 9.	Pine No. 11.	Elm.		Horse chestnut.		Apple No. 18.	Mean loss.
				No. 2.	No. 10.	No. 16.							No. 3.	No. 17.	No. 14.	No. 15.		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
1917.																		
July	0.215	1.86	[3]5.370	0.061	....	....	0.023	0.061	0.068	0.107	....	....	0.103	....	....	....	....	....
August	.173	1.93	[3]6.260	.039	....	....	.041	0.42	.032	.065	0.083	0.080	.075	....	....	....	....	....
September	.133	.83	[3]3.820	.063	....	....	.045	.027	.066	.028	.009	.0[illegible]8	.037	....	....	....	....	....
October	.126	3.47	[3]1.705	.039	0.083	....	.059	.085	.076	.068 .044	.080	.085	.054	....	0.076	0.064	0.076	....
1918.																		
May	.202	[4]2.20	5.220	.073	.087	0.034	.045	.065	.077	.041	.071	.081	.074	0.062	.068	.084	.090	0.069
June	[4].267	....	5.057	.126	.184	.130	.143	.158	.171	.166	.196	.146	.212	.155	.146	.156	.130	[4].158
July	.198	.52	5.928	.111	.103	.099	.081	.063	.110	.083	.120	.105	.085	.079	.024	.122	.077	.090
August	.183	1.58	6.323	.064	.108	.081	.027	.044	.087	.041	.082	.076	.114	.074	.041	.081	.055	070
September	.117	7.08	2.744	.107	.117	.102	.046	.039	.087	.031	.117	.117	.077	.077	.102	.077	.087	.088
October	.179	2.80	2.190	.042	.062	.027	.055	.065	.079	.031	.037	.104	.046	.036	.041	.074	.058	.056

[1] 4-foot U. S. W. B. standard pan.
[2] Shrubs, no record of trunks.
[3] A few days missing during the month. Totals increased proportionally.
[4] Record of one storm only.

COMPARATIVE CATCH OF DIFFERENT INTERCEPTOMETERS UNDER THE SAME TREE.

In most cases the interceptometer was placed either within about 4 feet of the trunk of the tree, or in the case of the larger trees, about midway from the trunk to the periphery. In the case of the hemlock, maple, and horse-chestnut trees, an additional interceptometer was placed just within the periphery of the tree, with a view to determining the extent of watershed effect afforded by the tree crown. The branches of the tree above the peripheral interceptometer were at heights of about 10 feet in the case of the horse chestnut and maple and 20 feet in the case of the elm. It was early discovered that the peripheral interceptometers placed in this way would not give reliable results. In many cases, especially when the rain fell at an angle, or came from the same side of the tree on which the interceptometer was placed, the interceptometer would catch direct rain.

The peripheral interceptometers caught about 70 per cent of the true rain, as compared with about 60 per cent for the others. The peripheral interceptometers apparently caught the direct rain in about one-half the showers, which would account for the increased catch.

The results, as far as they go, do not indicate any considerable watershed effect, and it appears that results obtained from interceptometers placed about midway between the tree trunk and the periphery of the crown give results which may be accepted as fairly representing the average interception underneath the entire projected area of the tree crown.

three tree crowns, that is, interceptometers were placed in geometrical order, without reference to the character of the foliage above them. They were placed at angular spaces of 60 degrees around the center, and at distances alternating 10 and 5 feet, beginning 10 feet to the north of the center. The center used was the center of the tree, except in the case of the hemlocks, where it was the center of a group of three trees, about 18, 8, and 12 inches in diameter, respectively, standing nearly in line, the larger trees 15 feet part, and the smaller tree between them.

Results obtained from these groups of interceptometers in four showers, and the averages, are shown in the accompanying Table No. 18, in column No. 3, of which is also shown the character of the cover over each interceptometer. Some of these interceptometers were partially outside of the projected area underneath the tree crown. Others had only thin foilage over them. Those marked "Thick" agree generally for the same tree. These were all underneath portions of the tree crown where there was nearly a complete roof of foliage, or representing average conditions for well-developed growth, subject to the natural requirement that the leaves must have a suitable exposure to the light. The interceptometers marked "Thick" in the subjoined table represent conditions substantially the same as those used in the two years' experimental series. At the same time, Table No. 18 shows that the thicker and denser the foliage, the smaller in general is the amount of rain caught by a gauge underneath the tree.

TABLE No. 18.—*Comparative catch of interceptometers under the same trees.*

Date, June (1919)			26	27	20	27	Average.
Shower began			2:00 p. m.	9:30 p. m.	9:06 a. m.	8:40 a. m.	....
Shower ended			3:15 p. m.	11:30 p. m.	10:30 a. m.	4:30 p. m.	....
Duration, hours			1.250	2.000	1.400	7.830	3.120
Precipitation, inches			.040	.170	.250	.290	.187
Precipitation, inches per hour			.032	.085	.179	.037	.083
Position.	Distance (ft.).	Character of cover.	Amount caught, inches.				
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
		HORSE-CHESTNUT.					
N.	10	Medium	0.017	0.122	0.218	0.242	0.1498
N. 60° E.	5	Thin (edge)	.025	.178	.210	.266	.1697
S. 60° E.	10	do	.008	.090	.162	.162	.1055
S.	5	Thick	T.	.098	.090	.186	.0935
S. 60° W.	10	Very thick	T.	.074	.146	.138	.0895
N. 60° W.	15	Thick	T.	.058	.074	.130	.0655
		Average	.0083	.1033	.1500	.1873	.1122
		APPLE.					
N.	10	Medium	0	0.058	0.170	0.146	0.0935
N. 60° E.	5	Thick	T.	.082	.122	.146	.0875
S. 60° E.	10	Edge thin	.033	.178	.130	.258	.1497
S.	5	Thick	.008	.082	.066	.130	.0715
S. 60° W.	10	Edge open	.042	.194	.258	.258	.1880
N. 60° W.	5	Thick	0	.082	.202	.186	.1175
		Average	.0138	.1127	.1580	.1873	.1178
		HEMLOCK.					
N.	10	Edge high, med.	T.	0.042	0.122	0.154	0.0795
N. 60° E.	5	Thick	.008	.098	.130	.154	.0975
S. 60° E.	10	Thin, underbrush.	T.	.090	.130	.186	.1015
S.	5	Thick	.008	.138	.130	.154	.1075
S. 60° W.	10	Edge high	.008	.114	.315	.186	.1558
N. 60° W.	5	Very thick	.008	.082	.122	.082	.0735
		Average	.0053	.0940	.1582	.1527	.1025

RELATIVE INTERCEPTION IN FOREST AND OPEN.

Since the trees in all cases in the author's experiments, excepting, perhaps, the hemlock, were more exposed than trees in a dense forest, it is possible that the results do not accurately represent the rainfall interception which would take place within the body of the forest. Information regarding the interception by scattered trees and shrubs such as cover large areas and from orchards and hedges is, however, useful and important, and furthermore, the difference in the results here obtained from those which would have been obtained had the interceptometers been placed in a dense forest can be inferred to some extent at least.

So far as can be judged from the limited data available, the storage loss in an active wind is reduced to from one-third to one-half of the amounts occurring when the air is still. The evaporation losses are quite certainly increased by wind action to at least an equal degree and probably more. There is, of course, some wind effect even in the denser forests, especially near the tree tops.

Barring differences in evaporation rate due to difference in humidity and temperature within the forest and in the open, which differences are at a minimum during rain, it appears that the interception loss from trees in the open is probably less in very light showers and more in long rains than from trees within a forest. In a forest, however, the entire interception loss does not take place on the trees. If there is an undergrowth, the water dropping from the trees may be intercepted by shrubs, herbs, or grasses underneath the trees.

147217—19——2

WINTER AND SUMMER INTERCEPTION COMPARED.

Ebermayer's experiments (Table No. 5) show greater interception losses for the same precipitation in the winter than in the summer, although the difference in the case of broad-leaved trees is relative slight. The Swiss experiments (Tables Nos. 13 and 14), on the other hand, show considerably greater losses during the summer months than in the winter months, especially in the case of the beeches.

J. C. Alter (MONTHLY WEATHER REVIEW, May, 1911, **39**: 760) states:

"It has been observed in well forested regions that a downfall of 4 or 5 inches of snow may be almost entirely supported by the branches of the evergreen trees, even when deposited in a high wind, provided the snow was sufficiently moist when it fell. In such cases a subsequent freeze may attach it firmly to the branches. Since nearly all heavy snows come during only moderately cold weather, and often actually begin as rain, the amount of moisture that clings to the trees to be subsequently evaporated is very great. It has been variously estimated at from 50 to 80 per cent of the fall of snow, under the varying conditions that exist over the forest."

Anyone who has stood beneath a tree to escape a driving rain would be pretty certain to conclude that the amount of interception is greater in summer than in winter for broad-leaved trees.

The small difference indicated by some forest experiments between the percentage of interception in winter and summer by deciduous trees was noted by Harrington (**1**). He says:

"Admitting (though there are some reasons for doubt) that the rainfall is actually the same over a wood and a place outside but near, this small action of the foliage as compared with the branches and twigs requires explanation, and, whatever the explanation may be, it must apply to deciduous trees, as evergreens show no difference in these months. No satisfactory explanation occurs to me."

The apparently anomalous results of the experiments are, however, capable of explanation, and are probably due to a combination of several causes.

1. The winter precipitation falls largely as snow and not as rain. The storage capacity of the trunks, branches, and twigs of deciduous trees for either moist snow or for rain or sleet, falling under conditions such that the precipitation freezes to the tree surfaces, is undoubtedly very much greater per unit of surface than the storage capacity of leaves or branches of trees for summer rain, so situated as to be substantially protected from the wind. Unlike rain, intercepted snow does not run down the trunks of the trees.

2. The angle to the vertical at which snow approaches the earth is, as a rule, very much greater than the inclination of rain. If we view the projection of a forest on a horizontal plane, there will be seen in most cases a considerable percentage of open spaces. Viewed from above, at any angle to the vertical, the percentage of open space visibly decreases as the angle increases, becoming in most cases zero for angles to the vertical as great as those at which snow ordinarily falls. Thus it appears that the effective interception surface is likely to be considerably greater for precipitation falling as snow than for precipitation falling as rain, owing to the greater inclination of the former.

3. At many of the forest meteorological stations the average precipitation rate is less, and the duration greater, in winter than in summer, so that, the percentage of inter-

ception loss being greater for light than for heavy storms, and increasing with the storm's duration, one would naturally expect in these conditions that the average percentage loss in winter, other things being equal, would be relatively greater than in summer. In the case of rain falling during cold weather, the increased surface tension may tend to concentrate interception storage into drops, reducing the film area and evaporation loss.

In the general formula

$$J = S_J + KE_r T_s$$

the storage S_J may be much greater in winter than in summer, E_r is less, but T_s is greater, for winter than for summer conditions.

4. The heaviest interception of snow by needle-leaved trees, such as spruce and fir, is more likely to slide off than is the interception in lighter snow storms. A comparison of measured precipitation and run-off in the winter season for northern streams often shows the apparent water losses remarkably small, so small as to be apparently incompatible with interception losses in winter equal to those in summer.

The average seasonal results at Haidenhaus and Adlisberg in terms of interception loss per rainfall day, as derived from tables Nos. 13 and 14, are as follows:

Mean interception loss per rainfall day.

	May-October, inclusive.	November-April, inclusive.
Haidenhaus:	*Inches.*	*Inches.*
Beech	0.083	0.026
Fir	.129	.060
Adlisberg:		
Beech	.023	.014
Fir	.078	.067

These data show the summer interception loss in all cases to be greater than that for the winter, and for the Haidenhaus station the summer loss for both beech and fir is more than double the winter loss.

It is significant that at both stations the excess of summer over winter losses is greater in the case of beech than in the case of the fir trees.

It seems impossible, without further experimental data, to determine definitely the winter interception losses. Probably the best that can be done is to assume for the present that in the case of evergreen trees, under average conditions, the winter and summer losses by interception are about equal. As regards broad-leaved deciduous trees, it is the author's opinion that the winter interception losses for average conditions in northern United States are probably about 50 per cent of the summer interception losses. It appears likely that under some special conditions, as, for example, where the summer precipitation is concentrated in short, heavy showers, and the winter precipitation occurs in numerous light showers of long duration, the winter interception losses from such trees may approach equality with or even exceed the summer interception losses.

Interception of snow in forests in Russia has been determined by the Imperial Agronomic Institute of Moscow by measurements carried on for five years. Numerous snow samples were taken, weighed, and reduced to equivalent water depths in forests of different kinds, as shown in Table 19. It will be noted that the water equivalent of snow in the older and denser forests ranged from 40 to 80 per cent of the average water equivalent of snow on the ground in small clearings and young plantations, for which the measured depth is probably very near the true actual depth of snow falling over the forests. The depth in cultivated fields has no particular bearing, as it was affected largely both by drifting and melting.

TABLE 19.—*Russian experiments on the interceptive influence of forests on snowfall (Zon.).*[1]

	Number of areas examined.	Number of measurements of snow depth.	Number of snow samples weighed.	Average thickness of snow.	Water equivalent of snow depth.
(1)	(2)	(3)	(4)	(5)	(6)
				Inches.	*Inches.*
1. Young plantations (2 to 4 years old) and small clearings within the forest	20	259	7	21.9	5.1
2. Birch forest (35 to 75 years old)	11	377	27	22.2	5.0
3. Oak forest (25 to 90 years old)	2	63	3	23.5	5.6
4. Pine forests	32	887	56	15.5	3.1
Young (25 to 35 years old)	25	662	43	15.2	3.1
Old (60 to 90 years old)	7	225	13	16.4	3.2
5. Spruce forest (25 to 35 years old)	21	460	29	9.7	2.1
6. Pine forest with admixture of birch (65 to 75 years old)	4	6	3	20.0	4.4
Pine forest with admixture of larch (25 to 35 years old)	3	74	2	15.2	3.1
Pine forest with admixture of spruce (35 years old)	5	157	9	12.9	2.9
7. Spruce forest with admixture of larch	3	57	2	14.1	3.1
8. Cultivated field	1	332	8	13.0	3.1

[1] Final report of the National Waterways Commission. . p. 241.

SECONDARY INTERCEPTION.

As regards forest and brush land, the herbaceous vegetation, if any, should be included in estimating the extent and condition of cover. In the European forest experiments, from which most of our data of interception by forests are derived, it appears that the rain gages were not as a rule placed underneath a growth of underbrush, and that what may be termed secondary and tertiary interception—i. e., water caught and retained by underbrush beneath the main forest growth, and that caught and retained by herbaceous vegetation beneath the underbrush, have not been taken into account in the experimental data.

In the case of orchards, for example, either where crops are grown between and under the trees, or where the soil is sodded, the total interception loss is the sum of the losses for partial cover by trees and for complete cover by sod or crops, the latter is in part secondary.

Table 20 contains illustrations of the increase in interception by undergrowth. The experimental results for pan No. 4 under willow brush, figure 16, indicate that the interception loss from dense shrubs may equal that from mature trees in light showers, and is one-half to two-thirds as great in heavier rains. The total interception is somewhat less than the sum of the interception losses for the different classes of vegetation, since the lower layer or layers of vegetation receive only the part of the total precipitation not intercepted by the higher vegetation.

Using the type of formula

$$J = a + bP$$

and letting J_1, J_2, J_3 represent respectively the interception loss for the upper (trees), middle (underbrush), and lower (herbs), layers of vegetation, and J the total, then

$$J_1 = a_1 + b_1 P$$
$$J_2 = a_2 + b_2(P - J)$$
$$J_3 = a_3 + b_3(P - J - J_1)$$
$$J = c_1 J + c_2 J_2 + c_2 J_3$$

where c_1, c_2, and c_3 are projection factors, or proportions of the total ground area which would be shaded by a vertical sun over the different classes of vegetation.

Allowing for reduced density of cover, and in the light of the results of forest experiments on comparative evaporation rate in woods and open, the coefficients b_2 and b_3 may fairly be taken at one-third to one-half, or say 40 per cent of their values for open exposures.

The importance of the lower vegetation is illustrated by the following calculation, for a maple forest with a dense growth of underbrush such as sometimes occurs.

Using the following values of the constants:

Layer.	a	b	c
Maple trees	0.03	0.23	90
Underbrush	.02	.115	70
Herbs	.01	.05	40

Then for $P=0.1$, $J_1=0.053$, and $P-J=0.047$; $J_2=.0254$; $P-J_1-J_2=0.0216$; $J_3=.011$, and $J=0.0477+0.0178+0.0044=0.0699$.

Here secondary interception increases the total loss about 50 per cent.

RAINFALL INTERCEPTION BY CROPS AND OTHER HERBACEOUS VEGETATION.

The rainfall loss by interception from growing crops and vegetation other than forests has not hitherto been experimentally determined. For crops like wheat, corn in drills, grass, peas, millet, etc., which, when approaching maturity quite fully shadow the ground, it appears certain that the interception percentage approaches in value that for broad-leaved forests. Other crops, like corn, potatoes, tobacco, cotton or beans, planted in hills, do not as a rule completely shadow the ground at any stage of their growth.

Experiments were made by the author on two dates in 1915 with a view to determining the relative interception under trees under different conditions, and under various other kinds of vegetable cover from the same precipitation. The results are contained in the accompanying Table No. 20. It will be noted that in all cases the percentage loss by interception was larger on July 2 from a rainfall of 0.27 inch than that on July 1 from a rainfall of 1.82 inches.

TABLE No. 20.—*Comparative interception for different vegetation.*

	July 1, 1915.			July 2, 1915.[1]		
	Inches caught.	Interception.		Inches caught.	Interception.	
		Inches.	Per cent.		Inches.	Per cent.
United States Weather Bureau rain gage in open	1.82	0	0	0.27	0	0
North side 18-inch diameter horse-chestnut	1.30	0.52	29	0.08	0.19	70
South side 18-inch diameter horse-chestnut	1.20	0.62	34	0.04	0.23	85
Horse-chestnut and rosebush	0.70	1.12	61.5	0.054	0.216	80
Under 10-inch diameter elm[2]	2.10	−0.28	......	0.122	0.148	55
Elm, 10 inches diameter, with undergrowth	0.70	1.12	61.5	0.100	0.17	63
Soft maple, 6 inches diameter	1.40	0.42	23.1	0.047	0.223	83
Maple brush	1.60	0.22	12.1	......	......	......
Rye	1.70	0.12	6.6	0.122	0.158	59
	1.40	0.42	23.1	0.119	0.151	56
Red clover, a few spears over gage	1.60	0.22	12.1	0.23	0.040	15

[1] Probably interception is somewhat too large, owing to evaporation loss before measurement.
[2] Water dripped into gage from end of overhanging branch.

The interception by rye was about one-half that by mature horse-chestnut trees in a heavy shower, and about three-fourths in a light shower. Red clover intercepted 20 to 40 per cent as much.

Interception by herbaceous vegetation appears to be more largely a matter of storage than in the case of interception by trees. The extent and nature of interception storage for some plants is illustrated in figure 2.

In the absence of more experimental data, the interception storage for various crops has been estimated from observations similar to those shown in figure 2, and the evaporation coefficients have been assumed about in proportion to the plant surface or density of cover as compared with trees.

According to Zon (**10**), Ney estimated the ratio of foliage area to the area covered by forests and crops as follows:

	One side.	Both sides.
Middle-aged beech forest	8.4	16.8
Cereals	7.4	14.8
Clover	5.6	11.2
Grass	4.8	9.6

These figures indicate that the density of interception cover for grass and cereals is five-eighths to seven-eighths that for beech forests.

The above figures are for leaf surfaces only, not including stems and trunks. The entire leaf surfaces of a plant are not usually fully wetted, but the deficiency is partly made up by the moist surfaces of stems and trunks.

In the case of rapidly growing crops, as corn and grains, the interception evidently varies with the stage of growth. In general the density of cover and the projection factors each increase about in proportion to the height of the plant for field crops which do not completely shadow the ground.

In view of the need of experimental data on the interception losses from field crops, the following methods of experimentation are suggested:

In the case of good-sized plants, such as corn or potatoes, one or more plants may be grown in a potometer of suitable size, the surface of the potometer being covered with a thin rubber sheeting, secured tightly around the stem or stems of the plants, to prevent rain entering the potometer. When exposed, the potometer should stand in a pan of considerably larger size, placed alongside of another similar large pan containing no potometer. The difference in the amount of rain caught in the two large pans, reduced to equivalent depth on the projected area of the plant, will represent the total interception loss by the plant.

In the case of grasses or small grains, this method can not be applied, but the interception loss can be approximately determined as follows:

The grass or grain is grown in duplicate potometers. The transpiration loss from both potometers is determined by weighing the potometers at the beginning and end of a given time interval before a rain. During rain one of the potometers is exposed to the rain, and the other is exposed to similar air conditions, but protected from rain. At the end of the rain, after the interception storage has evaporated from the plants in the exposed potometer, both are again weighed, and a second test of the relative transpiration rates is made. The weights of the exposed potometers will give the ratio of the transpiration loss during the rain to the transpiration loss preceding and following the rain. Applying this correction ratio to the measured transpiration loss for the exposed potometer preceding and following rain will give

the approximate transpiration loss for the exposed potometer during the rain.

Since the soil of the exposed potometer is uncovered, it will catch the entire rain less the interception, and the interception loss from the exposed potometer will be approximately equal to the measured precipitation in a rain gage, minus the gain in weight during the rain of the exposed potometer reduced to inches depth on the surface, plus the transpiration loss similarly expressed.

Pending the acquisition of more experimental data, tentative formulæ for interception by crops have been developed, as described in a subsequent paragraph.

WORKING FORMULAS FOR INTERCEPTION LOSS.

In view of the fact that the author's experiments on trees represented mainly conditions in hedges or open, and that in some cases the experiments apparently did not show true average conditions, and for trees with high crowns did not indicate the full interception storage which ordinarily occurs, experimental formulae have been somewhat revised for practical working purposes.

Additional formulæ have been prepared to represent conditions in woods, and for field crops. These formulae are given below.

In the case of field crops, the interception loss has been assumed proportional to the height of the plants at the date for which the calculations were made. A column has been added, showing the average projected area shaded by the plants. This is in most cases, except grasses and drilled grains, a function of the height of the plant. The formulæ represent interception loss on the projected area.

In the case of dense woods, the projected area may closely approach but seldom quite equals 100 per cent of the total area. For thin woods, such, for example, as scrub or jack pine lands, the projected area is commonly 33 to 66 per cent of the total. In scattered groves or brush pastures, it may have any value from zero to 100 per cent.

To obtain the mean interception depth over the total wooded or cropped area, the calculated interception loss is to be multiplied by the projection factor.

The formulas given for woods differ from those for trees of the same kind in the open, in the use of a larger constant for interception storage and a smaller evaporation factor. For average showers, the resulting loss is about the same for a given tree in the woods as in the open, but for heavy long continued rains, the formulas for woods give smaller results.

In the case of many crops, such as corn, cotton, grass, or tobacco, the density of the interception cover increases nearly in proportion to the height of the plant. For this reason the factor h is necessary in the formulas for crops.

In the case of trees, while it is true that Riegler's experiments show somewhat greater interception loss for large mature beeches than for younger trees, yet the difference is by no means as great as in the case of cultivated crops. As regards trees, especially in the woods, the effect of growth, in many instances, is to elevate the entire crown of the tree to a greater height. This may be accomplished by the lower and more shaded branches dying as the upper branches continue to grow. As a result, the density of cover or its thickness in a given vertical line increases less rapidly than the height of the tree.

Again, where the stand is very close, the crowns of adjacent trees may overlap. As a result, however, of requirement for light and air, the density of cover of overlapping crowns is usually no greater than the average density of cover under a single tree, although the projection factor would naturally be greater the thicker the stand of the trees. No attempt has been made to allow for variation in density of cover, but an allowance for this may be made, based on judgment and included in the projection factor.

In practical calculations, additional formulas will be needed for various classes of vegetation, such as sugar cane, rice, cranberries, heather, swamp elder beds, sagebrush, chaparral, cattail flags, and various truck crops where grown extensively, such as sugar beets, onions, or celery, as well as for additional kinds of trees.

The close agreement in amount of interception loss by the different kinds of trees, on the one hand, and in the apparent interception loss by different classes of crops of similar nature, as indicated by observations of the extent of cover and interception storage, leads to the suggestion that for practical purposes in calculations of interception losses, various kinds of trees or crops can be combined in a single group, and the same formula used for all plants of a given group.

WORKING FORMULAS FOR PRIMARY INTERCEPTION LOSS PER SHOWER ON PROJECTED AREAS OF TREES AND PLANTS.

Orchards	$J=0.04+0.18\ P_s$
Chestnut, hedge and open	$J=0.04+0.20\ P_s$
Chestnut, in woods	$J=0.06+0.15\ P_s$
Ash, hedges and open	$J=0.015+0.23\ P_s$
Ash, in woods	$J=0.02+0.18\ P_s$
Beech, hedges and open	$J=0.03+0.23\ P_s$
Beech, woods	$J=0.04+0.18\ P_s$
Oak, hedges and open	$J=0.03+0.22\ P_s$
Oak, woods	$J=0.05+0.18\ P_s$
Maple, hedges and open	$J=0.03+0.23\ P_s$
Maple, woods	$J=0.04+0.18\ P_s$
Willow shrubs	$J=0.02+0.40\ P_s$
Elm, hedges and open	$J=0.03+0.23\ P_s^{\frac{1}{2}}$
Elm, woods	$J=0.04+0.18\ P_s^{\frac{1}{2}}$
Basswood, hedges and open	$J=0.03+0.13\ P_s^{\frac{1}{2}}$
Basswood, woods	$J=0.05+0.10\ P_s^{\frac{1}{2}}$
Hemlock and pine, hedges and open	$J=0.03+0.20\ P_s^{\frac{1}{2}}$
Hemlock and pine, woods	$J=0.05+0.20\ P_s^{\frac{1}{2}}$

WORKING FORMULAS FOR PRIMARY INTERCEPTION LOSS PER SHOWER ON GRASSES AND FIELD CROPS.

	Per cent.[1]
Clover and meadow grass, $J=(0.005+0.08\ P_s)h$	1.00
Forage, alfalfa, vetch, millet, etc., $J=(0.01+0.10\ P_s)h$	1.00
Small grains, rye, wheat, barley, $J=(0.005+0.05\ P_s)h$	1.00
Beans, potatoes, cabbage, and other small hilled crops, $J=(0.02+0.15\ P_s)h$	$\frac{1}{4}\ h$.
Tobacco, $J=(0.01+0.08\ P_s)h$	$\frac{1}{5}\ h$.
Cotton, $J=(0.015+0.10\ P_s)h$	$\frac{1}{3}\ h$.
Buckwheat, $J=(0.01+0.12\ P_s)h$	1.00
Corn, planted in hills or rows, $J=(0.005+0.005\ P_s)h$	0.1 h.
Fodder corn, sorghum, Kaffir corn, etc., sowed in drills, $J=(0.007+0.006\ P_s)h$	1.00

Average height of plants in feet$=h$.

CALCULATION OF INTERCEPTION LOSSES.

It is evident that interception losses, which may amount to one-third or more of the precipitation, should not be disregarded in estimating run-off or yield of drainage basins. Heretofore they have been usually included in general water losses and not separately estimated. More accurate results can often be obtained by direct estimation of the interception losses.

This may be accomplished well enough for some purposes by the use of percentage factors. Greater accuracy will usually be obtained by the use of interception formulas, taking into account the rainfall distribution. For such calculations the data needed are: The monthly precipitation, the number of rainfall days, the average number of showers per rainfall day, and the character, pro-

[1] Ordinary projected area of total.

jection factor, and density of cover or stage of development of the vegetation.

As an example, the following calculations have been made of the interception losses on the Seneca River drainage basin above Seneca Falls, N. Y., for the summer of 1915. The cultural conditions were determined by inspection and counting over sample areas or belts crossing the drainage basin. Areas devoted to roads and villages have been mainly included with grasslands, while an allowance for garden areas has been made in connection with truck crops.

During the months when the crop is generally harvested the interception loss may be taken as the mean of the amount for two conditions: (1) For mature crops, (2) for their residual stubble. Since grain stubble is usually seeded, or contains weeds, it affords a condition as regards water losses nearly identical to grass of equal height, and may be so considered. The estimation of interception losses in a given locality requires some knowledge of farm practice and the rotation of crops and usual dates of seeding and harvest, in order that fair allowance may be made for the portion of fallow, or newly plowed ground, and for other conditions dependent on farm practice.

The method of calculation of interception losses based on the average shower intensity does not take into account rainfall distribution to the same extent as a calculation based on individual rainfall amounts per shower or day. The labor involved in such calculations is, however, usually prohibitive. Light rains occur much more frequently than heavy ones, and occasion relatively greater interception losses. It follows that the use of the average monthly shower intensity in calculating interception is likely to lead to results slightly too small, in the majority of cases. If desired, a correction factor can be applied, based on the statistical law of distribution of showers of different amounts.

Table No. 21 shows the calculated interception losses for Seneca River Basin during the summer months. It will be noted that while the interception depth on the projected area, for full-grown crops, approaches in value that for trees, yet the average loss per unit area from crop land is much less than from wooded lands—(1) because the projection factor for many crops, especially when young, is smaller than for woods; (2) crops are at approximately their full stage of development, as a rule, for only one to three months per year. During the remainder of the growing season the loss from the small plants, or from the stubble subsequent to harvesting, is greatly reduced. The latter is the cause of marked decrease in the total interception loss for September, as compared with August, in Table No. 21. In the case of trees, the interception capacity remains nearly constant throughout the summer season.

If stubble or fallow land is allowed to grow up to weeds, it may increase the interception loss materially. The interception loss by some plants and weeds is greatly augmented when the plants are in blossom, as in the case of red clover. Wild carrot, which may grow up in a meadow after haying, often has 10 or more blossoms per square foot. Each flowering head is a sponge like structure, which persistently retains a teaspoonful or more of water after every rain. Weeds generally exert a pernicious influence in desiccating the ground through interception as well as in other ways.

In conclusion, credit is due to Mr. James Erwin, for patient, careful work in taking the large number of readings involved in the author's experiments, and to Dr. Floyd A. Nagler, and Mr. Geo. E. Cook, C. E., for the reduction of the several thousand observations involved in this study.

TABLE No. 21.—*Example of calculated interception losses over cropped area, Seneca River drainage basin above Seneca Falls, N. Y., 1914.*

	May.	June.	July.	Aug.	Sept.	Oct.	Total.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
P=precipitation on basin [1]	5.110	2.920	2.200	6.320	1.5700	1.920	20.040
d_p=rainfall days [2]	14.000	11.000	12.500	14.000	16.0000	10.000	77.500
$P_d=P/d_p$	.365	.265	.183	.452	.1000	.192	.259
S_n=number of showers [3]	21.000	16.500	18.800	21.000	24.0000	15.000	116.300
P_s=precipitation per shower	.243	.177	.117	.301	.0654	.128	.172
CROP.							
Meadow:							
Per cent of area	22.000	22.000	22.000	17.000	17.0000	17.000	......
Height=h	1.000	2.000	[4] .500	[4] .500	[4] .5000	[4] .500	......
$J=(0.005+0.08\ P_s)h$	.024	.038	.007	.015	.0050	.008	[5] 1.818
J^1	.111	.138	.029	.054	.0200	.020	.372
Pasture:							
Per cent of area	25.000	25.000	25.000	[6] 18.000	[6] 18.0000	[6] 18.000	......
Height=h	.500	.500	.500	.500	.5000	.500	......
$J=(0.005+0.08\ P_s)h$	.012	.010	.007	.015	.0050	.008	[5] 1.104
J^1	.063	.041	.033	.057	.0220	.022	.238
Wheat, rye, barley:							
Per cent of area	7.100	7.100	7.100	[4,6] 5.000	[4,6] 4.0000	[4,6] 4.000	......
Height=h	1.000	3.000	4.500	.500	.5000	.500	......
$J=(0.005+0.05\ P_s)h$	.017	.041	.049	.010	.0040	.006	[5] 2.352
J^1	.025	.048	.065	.010	.0040	.004	.156
Oats:							
Per cent of area	8.800	8.800	8.800	6.000	4.0000	4.000	......
Height=h	.500	1.000	2.000	[4,6] .500	[4,6] .5000	[4,6] .500	......
$J=(0.007+0.07\ P_s)h$	.012	.019	.030	.014	.0060	.008	[5] 1.687
J^1	.022	.028	.050	.018	.0060	.005	.129
Potatoes, beans, cabbage, etc.:							
Per cent of area	10.000	10.000	10.000	10.000	8.0000	2.000	......
Height=h	......	.400	.800	1.000	1.0000	1.000	......
$J_1=(0.02+0.15\ P_s)\frac{h^2}{4}$	......	.002	.006	.016	.0070	.010	[5] .800
J^1	......	.003	.011	.034	.0130	.003	.064
Corn:							
Per cent of area	4.400	4.400	4.400	4.400	4.4000	4.400	......
Height=h	[6] 0	0.700	2.500	5.500	6.5000	0	......
$J_1=(0.005+0.005\ P_s)\frac{h^2}{10}$	......	0	.003	.020	.0220	......	[5] 1.003
J^1	......	0	.002	.019	.0230	0	.044
Buckwheat:							
Per cent of area	......	......	2.700	2.700	2.7000	2.700	......
Height=h	......	......	.500	1.500	2.5000	.500	......
$J=(0.007+0.07P_s)h$	......	......	.008	.042	.0300	.008	[5] 1.872
J^1	......	......	.004	.024	.0190	.003	.050
Orchard and vineyeard [7]	5.000	5.000	5.000	5.000	5.0000	5.000	......
Trees:							
$J_1=(0.04+0.18\ P_s)\ 0.33$	.028	.024	.020	.031	.0170	.021	......
J^1	.029	.020	.019	.033	.0200	.016	.137
Grass:							
Height=h	1.000	2.000	.500	.500	.5000	.500	......
$J_1=(0.005+0.08\ P_s)\ h\times\frac{1}{2}$	.200	.032	.006	.013	.0040	.007	......
J^1	.021	.026	.006	.014	.0050	.005	......
Total of trees and grass J_1=	.048	.056	.026	.044	.0210	.028	[5] 4.269
Do. J^1	.050	.046	.024	.046	.0250	.021	.212
Woods (mixed hardwood):							
Per cent of area [8,9]	10.000	10.000	10.000	10.000	10.0000	10.000	......
$J=0.04+0.18\ P_s$	.084	.072	.061	.094	.0520	.063	[5] 8.268
J^1	.176	.119	.115	.197	.1250	.094	.826
Roads and bare surfaces	5.000	5.000	5.000	5.000	5.0000	5.000	......
No loss	......	......	......	......	......	......	0
Total intercepted loss	.476	.443	.352	.492	.2770	.188	2.228

[1] Weighted mean.
[2] Mean of Shortsville and Wedgewood.
[3] Estimated at 1.5 showers per rainfall day.
[4] Stubble.
[5] Total for 100 per cent area and all showers.
[6] Remainder new plowed.
[7] Estimated at 33 per cent of cover for trees, 2 rods apart, 20 feet diameter crowns. Grass interception under trees taken at 50 per cent of that in open or ½ of value for open meadow.
[8] Including wooded swamps.
[9] Estimated at 85 per cent cover and 50 per cent added for secondary interception.

NOTE.—Where crop does not afford complete cover, the projection factor is included in the formula, and the interception depth on the entire cropped area is designated J_1.

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THE SEASONAL DISTRIBUTION OF PRECIPITATION AND ITS FREQUENCY AND INTENSITY IN THE UNITED STATES.

By JOSEPH BURTON KINCER, Meteorologist.

[Dated: Weather Bureau, Washington, Oct. 11, 1919.]

SYNOPSIS.—Much has been written on the subject of precipitation in the United States, and a number of charts have been prepared and published showing its geographic distribution. Most of these, however, have represented the average annual amount, the only other available chart, where more than a very limited number of records were used, being that for the summer-half year.

The need for a series of charts based on all available records, showing the seasonal distribution of precipitation in this country has long been recognized, and the accompanying series is presented to meet this need. Those here shown consist of 12 monthly charts, and 1 for each of the 4 seasons, together with auxiliary maps for the seasons showing the percentage of the annual precipitation that occurs in each. The monthly and seasonal charts are based on all available records of sufficient length for such use, about 3,600 in number, reduced to a uniform 20-year period.

There are, in addition, a number of graphs showing for selected stations representing various rainfall types, the total precipitation in each season for each of the 20 years on which the maps are based. These show the relative variations in amount that may be expected from year to year in different sections of the country, and also give an indication of the dependability of the averages. In localities where the dispersions about the mean value are small, the latter is more indicative of the amount likely to be received in a particular year than in those where wide variations are shown by the graphs.

Departures from year to year from the average precipitation vary in magnitude inversely with the length of the season considered. The relative variations from the mean for the annual, the summer-half year, each of the 4 seasons, and for each of the 12 months, are graphically shown in figure 1, in such manner as to admit of direct comparison, as the scales are drawn on a comparable basis.

In addition to an indication of the variations from the mean precipitation that are likely to occur, it is important in considering the representations of precipitation charts to take into account the frequency with which significant amounts occur, the intensity of falls, and the subnormal frequency and duration. Auxiliary charts for use in this connection are presented as follows: Showing the average number of days annually with precipitation from 0.01 inch to 0.25 inch in 24 hours; the average number of days annually with 0.26 to 1 inch; the average annual number with more than 2 inches; the average annual number with more than 1 inch in an hour, and the maximum precipitation in 24 hours for the entire 20-year period. Also, the percentage of years east of the Rocky Mountains with 30 consecutive days or more, without 0.25 inch of rainfall in 24 hours from March to September, inclusive, and the greatest number of consecutive days without 0.25 inch in 24 hours for the same months. These auxiliary charts are based on the records of all regular reporting stations for the 20-year period from 1895 to 1914.

INTRODUCTION—RELATIVE UTILITY OF RAINFALL CHARTS.

Existing charts of the average precipitation for the United States are mostly for the year. Seasonal and monthly charts have been published, but these have been based on a limited number of stations and the isohyets drawn with little regard for topography. (See Weather Bureau Bulletins C, 1894, and D, 1897; also, Climatic Charts, edition of 1904.) The annual chart, however, is more frequently consulted, notwithstanding that seasonal amounts of precipitation are of great significance, especially in all sections where agricultural operations are conducted by ordinary farming methods. The principal difficulty in the application of statistics of annual precipitation arises from the fact that there is always a possibility, because of the long period covered, that large deficiencies in some portions of the year may be offset by excesses in others, and a disastrous drought during the season of critical plant development may thus be obscured in the annual total. Furthermore, the latter gives no indication of the seasonal distribution, which, agriculturally at least, is of great importance. For example, the average annual precipitation in the eastern portion of South Dakota is between 20 and 25 inches. This amount of precipitation may, or may not, be sufficient for successful agriculture as ordinarily practiced, depending wholly on the seasonal distribution and the locality as regards the amount of evaporation, soil texture and other factors. It is sufficient in eastern South Dakota, but in a locality with a more uniform seasonal distribution and more rapid evaporation it would be inadequate.

Monthly charts, also, are not entirely satisfactory for many purposes, because of the relatively large fluctuation in amounts from year to year in so short a period, and from the further fact that the means are sometimes unduly magnified by the occurrence of a few very heavy rainfalls which have little agricultural value. Seasonal charts are less subject to the limitations mentioned for annuals and monthlies and are, therefore, better representations of precipitation in its relation to agriculture; consequently their importance can hardly be overemphasized.

The accompanying series of charts includes a map showing the average amount of precipitation for the different sections of the country for each month of the year, Charts I to XII, and one for each of the four seasons, Charts XIII to XVI, each based on 3,600 records. There are also presented four charts, each based on 1,350 records, showing the percentage of the annual amount occurring in each of the seasons, figures 1–4, as well as graphs indicating for selected stations the variations from year to year in the annual, seasonal, and monthly totals. In addition, a few charts indicating the relative intensity of rainfall in different sections of the country, and the frequency and duration of certain features of subnormal rainfall for the warmer season of the year, are presented, as these factors have an important bearing on the significance of the averages for a series of years.

RECORDS REDUCED TO UNIFORM 20-YEAR PERIOD.

The records on which the monthly and seasonal charts are based were made at well-distributed points throughout the country, and have been reduced to the uniform period of 20 years from 1895 to 1914, inclusive. Of these, about 1,600 represent actual averages for the period

named, with short breaks interpolated, and the other 2,000 have been reduced to this uniform period by the method described in the MONTHLY WEATHER REVIEW, May, 1917, **45**, 333–335. The isohyets were drawn on bases showing, by hachures, the topographic features of the United States, and in accordance with the principles outlined in the paper referred to. The latest chart of annual precipitation in the United States constructed on these principles appeared in the MONTHLY WEATHER REVIEW for July, 1917, **45**, with comment by Prof. R. deC. Ward (pp. 338–345; reviewed, Science, July 19, 1918 pp. 69–71).

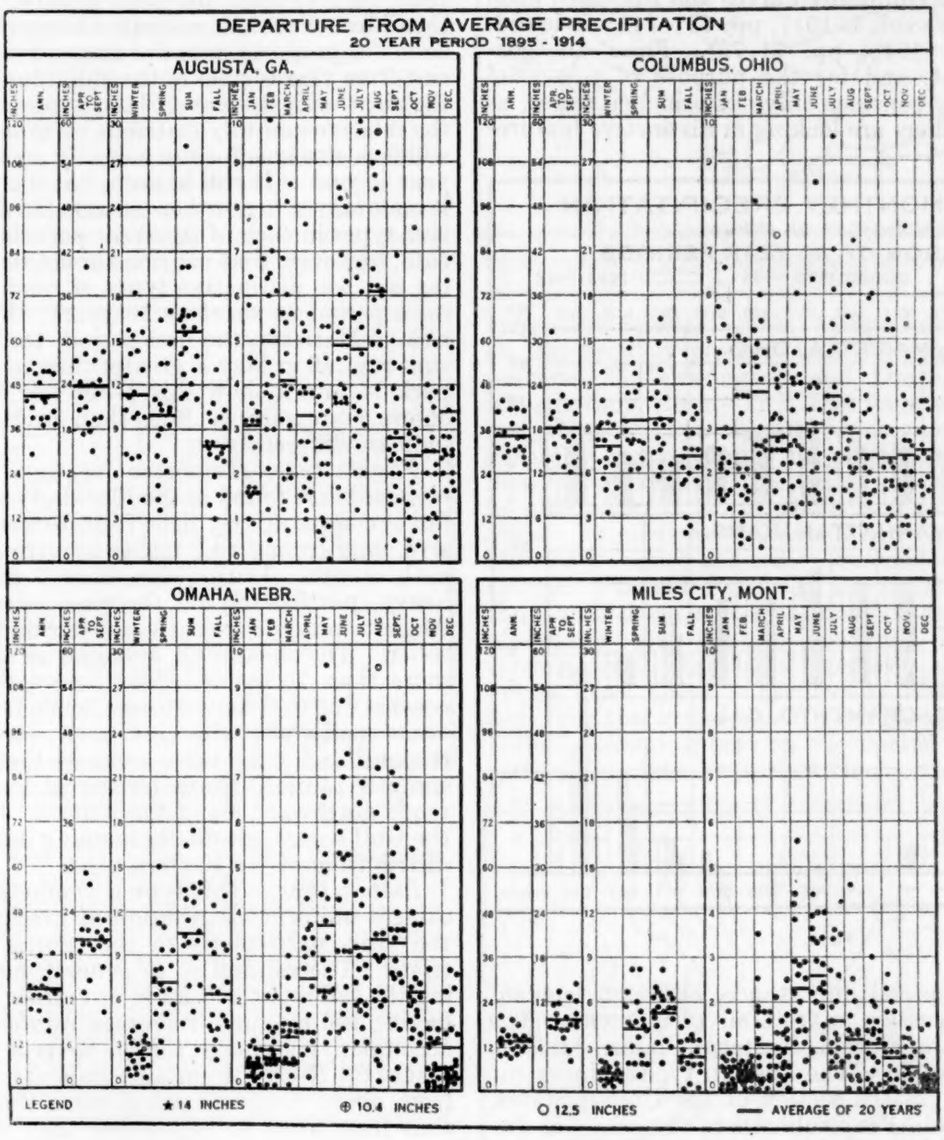

FIG. 1.

VARIATIONS FROM AVERAGE RAINFALL.

Owing to the fact that the significance that attaches to an average made up of variables of different magnitudes depends on the nature of the dispersions of the variables about the average, in considering precipitation charts based on an average for a series of years, the variation from year to year should be taken into account. These are not similar in the different sections of the country nor in different periods of the year, and they also vary with the length of the season represented. For the three classes of charts under consideration, annual, seasonal, and monthly, the annual has the smallest variations and the monthlies the largest, with the seasonal holding an intermediate position.

These dispersions about the mean are shown graphically in their relation to one another in figure 1. The records of four representative stations are shown in this graph: Augusta, Ga.; Columbus, Ohio; Omaha, Nebr.; and Miles City, Mont. To visualize comparability, the scales for the respective periods are proportioned to their length—that is, the scale for the summer-half year is twice as large as the annual, the seasonal twice as large as the summer-half year, and the monthly, in turn, three times as large as the seasonal. This affords a direct comparison of dispersions about the mean for the respective periods and indicates the amplitude of variation, which have an important bearing on the relative dependability of averages for different seasonal lengths. It will be seen from this graph that the annual amounts are grouped closely about the mean and that the individual totals from year to year have rather uniformly increasing and comparatively pronounced larger variations through the half year, quarter year, and monthly representations.

RAINFALL TYPES.

Omitting, for lack of space, a discussion of the indications of the individual monthly maps, Charts I to XII, we shall briefly consider, in a general way, the seasonal distribution of precipitation as indicated by these and the four seasonal charts combined. A number of distinctive types of distribution in the United States are well known, which in some cases, at least, are comparatively uniform over large areas. Prof. A. J. Henry has recognized 11 more or less distinct types (see Weather Bureau Bulletin D, p. 11), while Prof. Ward has pointed out 14 types, made composite curves and discussed each (see Geogr. Review, vol. 4, 1917, pp. 131–144; reviewed, Science, July, 19, 1918, pp. 71–72). From an agricultural standpoint, and for the purpose of this brief discussion, we may consider only six principal types, as a number of the others are lacking in distinctive features to make them of special importance, although relevant in a technical discussion of rainfall phenomena. The types considered are Florida, Eastern, Plains, Arizona, Sub-Pacific, and Pacific. The Eastern type includes the originally forested eastern section of the United States, excepting the Florida Peninsula where the seasonal distribution of rainfall is so distinct as to become a separate type; the Plains type includes the prairie and plains region extending from the Great Lakes and the central Mississippi Valley westward to the crest of the Rocky Mountains and southward to Missouri and Oklahoma; the Arizona type includes western Texas, New Mexico, and Arizona, as well as portions of southern Utah and Nevada, although it is not well marked in the latter localities; the sub-Pacific type occupies the central and northern portions of the Plateau region between the Rockies and the Sierra Nevada and Cascade ranges, and the Pacific type extends from these ranges westward to the Pacific Ocean.

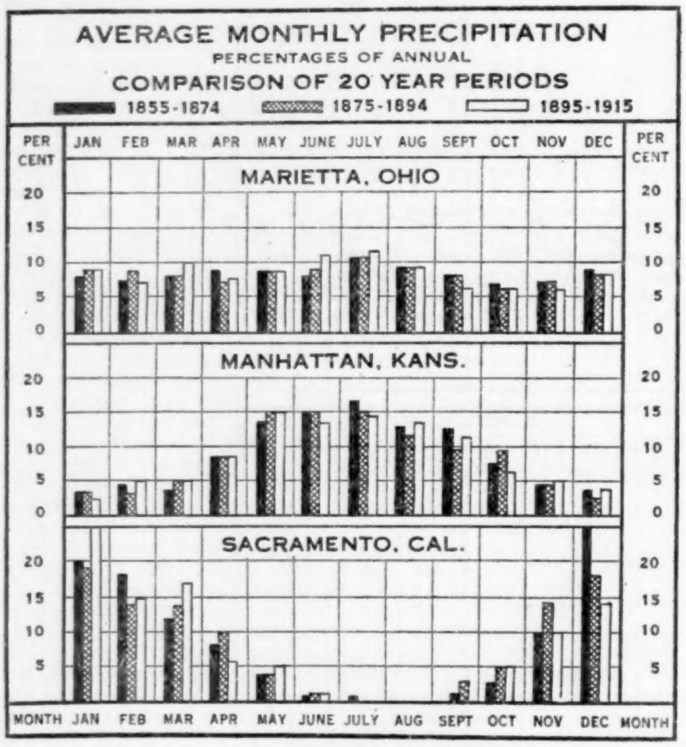

FIG. 2.

In this connection it is of interest to inquire as to the permanency of these various types of precipitation; that is, as to whether they would show material alteration by the adoption of a different series of years. If the precipitation of the year were equally distributed through the several months, each would receive substantially one-twelfth of the annual amount. Figure 2 presents data for Marietta, Ohio; Manhattan, Kans.; and Sacramento, Calif.; representing, respectively, the Eastern, Plains, and Pacific types of precipitation, indicating the percentage variations of the annual amount occurring from month to month for three consecutive 20-year periods, 1855 to 1874, 1875 to 1894, and 1895 to 1914. The variations for the different periods indicated for each of these types are about in proportion to the respective fluctuations occurring from year to year in the individual monthly amounts; that is, the Eastern and Plains types are more constant in the relative monthly distribution than is the Pacific type, which is also true for the monthly amount of rainfall from year to year. It will be seen that the typical distribution is maintained to a rather remarkable degree in the respective types in each of the three periods. The graphs indicate, however, that caution should be exercised in pointing out less distinctive types of rainfall from data based on a period as short as 20 years. For example, in the case of Marietta, the first period, 1855 to 1874, indicates that rainfall in May is greater than in June, but the other periods do not show this, while for Manhattan, the first shows more rain in June than in May, but the others indicate differently.

Florida type.—Important seasonal variations in precipitation are found in the Florida Peninsula. Here rainfall is comparatively light from November to May, inclusive, only from 2 to 3 inches occurring on the average in each month. During the other 5 months it is usually heavy, particularly on the west coast during July and August and on the east coast during September and October. The maximum averages in these months reach more than 10 inches. The heavy rainfall on the west coast is due to thunderstorms, while tropical storms which occasionally visit the east coast during this season are responsible for the large averages there. The heavy late summer rainfall, characteristic of the Florida type, extends northward along the Atlantic and westward along the Gulf coasts, gradually merging into the more uniform distribution of the Eastern type.

Eastern type.—This type is characterized by a comparatively uniform distribution of precipitation throughout the year, particularly in the central and northern districts. The rainfall is, in general, however, lighter during the fall months than in any other season. The areas having the maximum average rainfall, as shown on the accompanying charts, for the several months of the year east of the Rocky Mountains, indicate, in general, amounts from about 5 to somewhat more than 6 inches, except that from June to September they are 8 to more than 10 inches. Excluding a few restricted localities, the monthly charts show this area to be located as follows: In January, it occupies the lower Mississippi Valley; by February, it is farther east and overlies the southern portions of Mississippi and Alabama; in March, it includes the northern portions of these States with extensions into northern Georgia, western North Carolina, and eastern Tennessee; in April, it again appears in the lower Mississippi Valley, while in May it occupies western Arkansas and eastern Oklahoma. From June to October, inclusive, it is found in the Florida Peninsula, but in November, the only month with averages less than 5 inches, it occupies the Mississippi Valley from western Tennessee

southward, while in December it is restricted to limited areas in northern Mississippi and parts of Louisiana (see Charts I to XII). It will be noted by referring to figures 3-6, that the percentage of the annual precipitation occurring in each of the four seasons in the area covered by the Eastern type is comparatively uniform.

Plains type.—This is a very important type agriculturally, covering, as it does, much of the great interior wheat and corn belt. It is characterized by generous rains in the late spring and summer months and very light late-fall and winter precipitation. In portions of Montana and over small areas in the Dakotas and in eastern Colorado the total precipitation for the three winter months averages less than one inch, Chart XIII, while over the remaining area between the Rocky Mountains and a line extending from the Panhandle of Texas northeastward through central Minnesota, it is less than 2 inches. With the advent of warmer weather, however, the precipitation of this type increases rapidly. It will be noted by reference to the monthly charts that a large area immediately to the westward of the Mississippi River receives on the average more than 4 inches of rainfall during each of the months of May, June, and

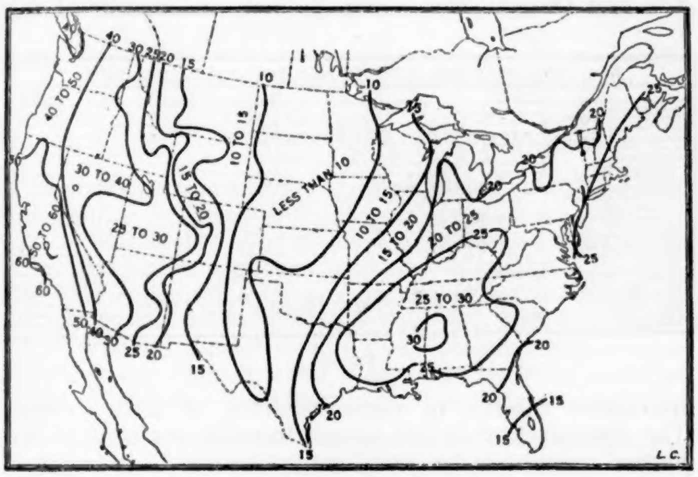

FIG. 3.—Percentage of annual precipitation occurring during the winter months, December-February.

July, Charts V, VI and VII. The seasonal distribution in percentage of the annual in much of the Plains is about as follows: Winter, less than 10 per cent; spring, 25 to 30 per cent; summer, 40 to 50 per cent; autumn, 15 to 20 per cent. The amount of stored soil moisture at the beginning of the growing season in much of the great grain-producing Plains region is not large, owing to the scanty winter precipitation, and here successful crop production depends largely on the amount of rainfall received during the period of actual growth. This is largely the reverse of conditions in the area covered by the Pacific type of precipitation.

Arizona type.—The distinctive feature of this type is heavy rainfall in July and August, when about 35 per cent of the annual amount of precipitation occurs. April, May, and June are usually the months of least rainfall, and during the other months the distribution is quite uniform. Summer rains in this area are due largely to thunderstorms during the warmer part of the day, while the amount and distribution of winter rains depend mostly on the frequency and position in latitude of cyclonic disturbances entering the United States from the Pacific Ocean. The Arizona type differs from the Plains type in that the heavier rains cover a shorter period of the year, and also, in that precipitation occurs more frequently in the afternoon, while in the Great Plains it is of more frequent occurrence at night.[1]

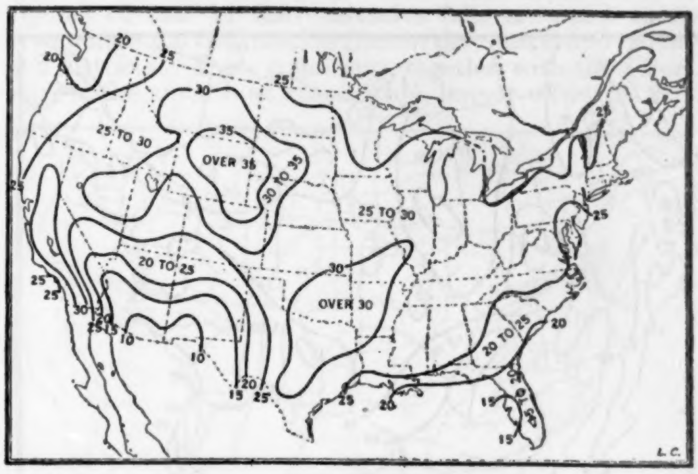

FIG. 4.—Percentage of annual precipitation occurring during the spring months, March-May.

Sub-Pacific type.—This designation has been given to the type of precipitation occurring in the eastern portions of Washington and Oregon and in Idaho, Nevada, and Utah. It differs from the Pacific type in the absence of a marked winter concentration and, generally speaking, may be considered of fairly uniform distribution through the year, except for the summer months when it is very light and in large areas negligible. In portions of Nevada and Utah more rain usually falls during the spring months than in any other season. The sub-Pacific is a transitional type between the Pacific type and that found in the northern Rocky Mountains and eastern foot-hills, which culminates farther east in the Plains type proper. The relation between these types is graphically illustrated by figures 3-5. For the winter season the highest percentages of the annual amount appear on the Pacific Coast, figure 3; in spring, this area comprises the northern Rocky Mountains and eastern foot-hill region, but high percentages extend westward into Idaho and Nevada and eastward well into the Plains, figure 4; while in the summer the

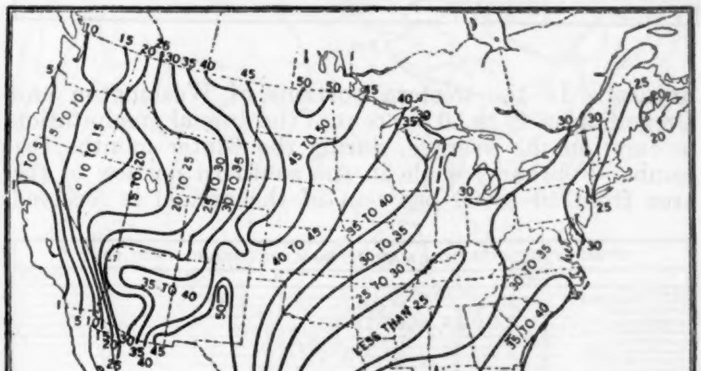

FIG. 5.—Percentage of annual precipitation occurring during the summer months, June-August.

[1] See "Daytime and nighttime precipitation and their economic significance," J. B. Kincer, MONTHLY WEATHER REVIEW, November 1916, 44: 628-633.

area appears still farther east and occupies the Plains proper, figure 5. Thus as the season progresses the area of relatively heaviest precipitation occupies successive localities from the Pacific coast to the interior Great

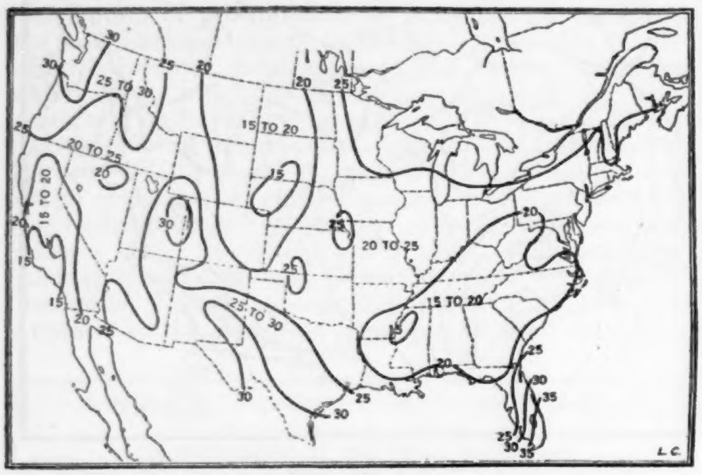

FIG. 6.—Percentage of annual precipitation occurring during the autumn months, September-November.

Plains. In the area covered by the sub-Pacific type of precipitation the actual amount is scanty throughout the year, except in the higher elevations of the more northern States, with agricultural operations depending largely on irrigation or dry-farming methods.

Pacific type.—This type is characterized by a marked winter concentration of precipitation and by a summer

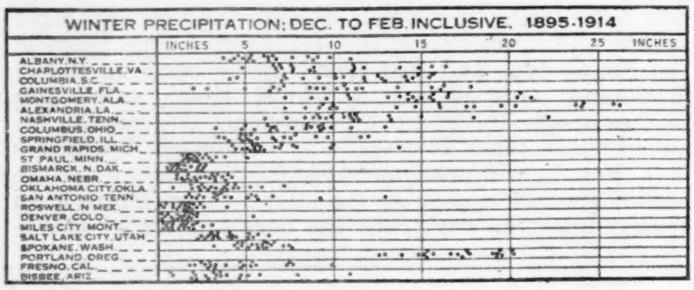

FIG. 7.

dryness. In the western portions of Washington and Oregon, from 40 to 50 per cent of the annual precipitation occurs, on the average, during the winter months, December–February, while in the southern portion of the area from 50 to 60 per cent of the annual is received

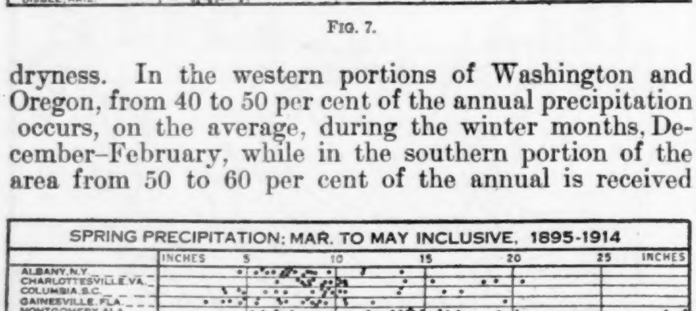

FIG. 8.

during this period, figure 3. The average total for the winter season ranges from more than 50 inches on the western slope of the Olympic Mountains in Washington to less than 4 inches in the southern end of the great valley of California (Chart XIII). For the three spring months, chart XIV, the amounts usually average about half as large as for the winter, except that in the Cascades they are about two-thirds as great. The proportion of the annual amount received during the summer months, June to August, figure 5 ranges from about 1 per cent in most

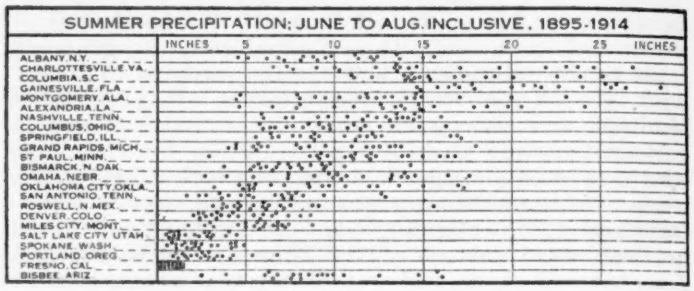

FIG. 9.

of California to 10 per cent in the vicinity of the Puget Sound. The rainy season sets in over the northern portion earlier than over the southern, the rainfall in November, Chart XI, becoming heavy in portions of Washington and Oregon, this being, in fact, the month of the

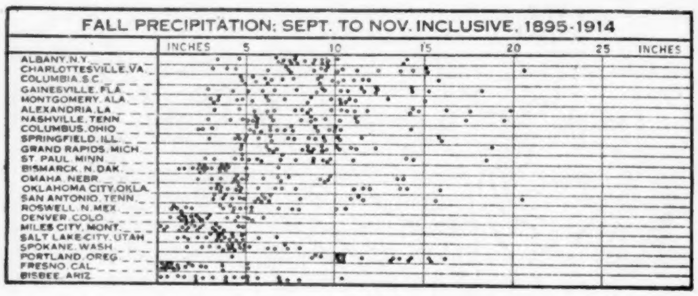

FIG. 10.

maximum rainfall in some localities of that section. The precipitation in fall ranges from 30 per cent of the annual amount in the northern portion to 15 per cent in the south, figure 6. In the area covered by the Pacific type of precipitation, fall-sown grain under the influence

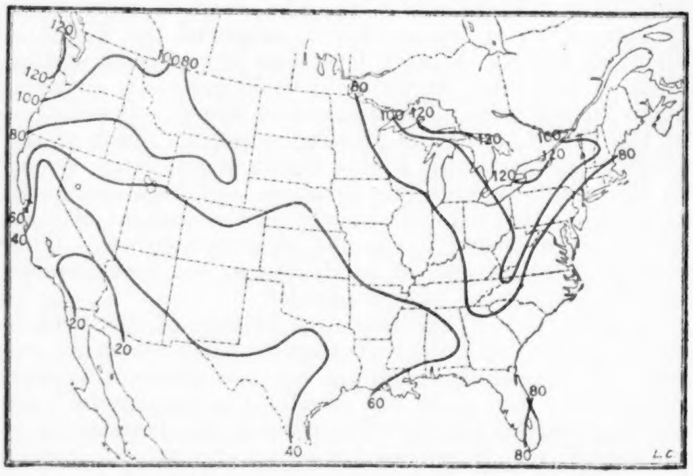

FIG. 11.—Average annual number of days with precipitation 0.01 to 0.25 inch.

of comparatively mild temperatures and ample moisture, grows steadily during the winter season and matures after the cessation of rain, largely utilizing the moisture stored in the soil during the wet winter months.

Figures 7 to 10 show for a number of representative localities, geographically arranged, the seasonal precipitation for each of the 20 years on which the four seasonal charts are based. On these graphs, the amount for the season in each year is represented by a dot. These show for different localities the variations in the seasonal amount that may be expected to occur from year to year.

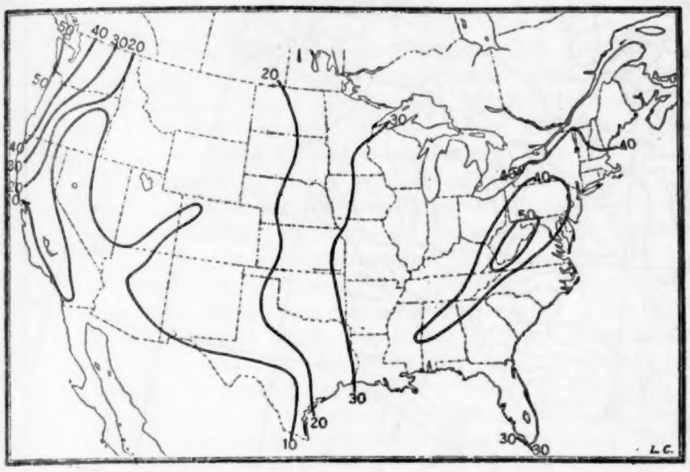

FIG. 12.—Average annual number of days with precipitation 0.26 to 1.00 inch.

RAINFALL FREQUENCY AND INTENSITY.

In studying the relation of precipitation to plant development the question of frequency of occurrence and intensity of falls should be considered. In regions of abundant rain there is a greater tendency to excessive amount and, consequently, a much greater loss by run-off which cannot be utilized for plant growth. On the other hand, the average precipitation in a given locality may be considerably less than in some other, but the rains may be better distributed as to frequency of occurrence, and may

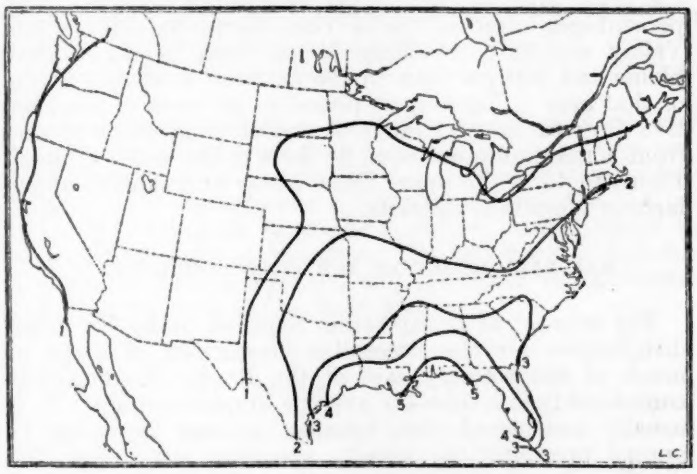

FIG. 13.—Average annual number of days with precipitation over 2.00 inches.

be less torrential in character for short periods, thus largely offsetting the difference in actual amount. For example, the average amounts of precipitation over the eastern section of the United Sates increase from the northern districts southward to the Gulf region, but the frequency of occurrence of moderate rains often increases in the opposite direction, this condition being especially marked during the spring months. It will be seen from figure 11 that the average annual number of days with rainfall between 0.01 and 0.25 inch varies from 60 to 70 days in the east Gulf section to 120 days in portions of the Lake region. It will also be noted from figures 13 and 14 that excessive falls are much more frequent in the Gulf section than in the central and northern districts. These conditions, together with the difference in the amount of evaporation, largely offset the dif-

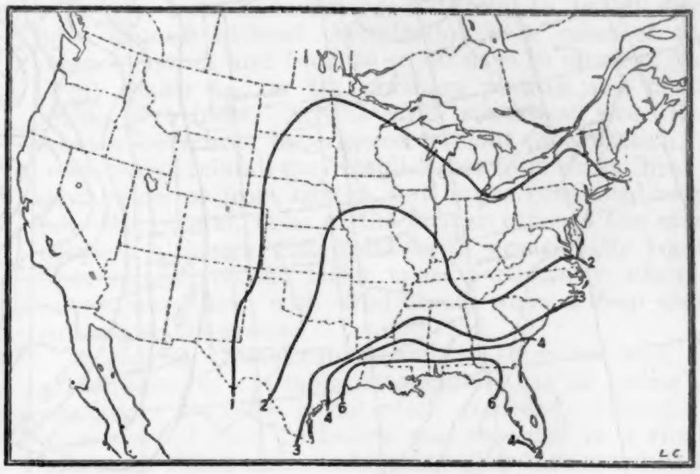

FIG. 14.—Average annual number of days with precipitation more than 1.00 inch in an hour.

ference between the actual amount of rainfall in the southern, and the central and northern districts.

Figures 11 to 15 show, respectively, the average annual number of days with precipitation between 0.01 and 0.25 inch; 0.26 to 1.00 inch; with more than 2 inches in 24 hours; with more than 1 inch in an hour, and the maximum precipitation in 24 hours for the entire period from 1895 to 1914. These charts indicate the relative frequency of precipitation of varying amounts in different sections. They are based on 200 regular reporting stations.

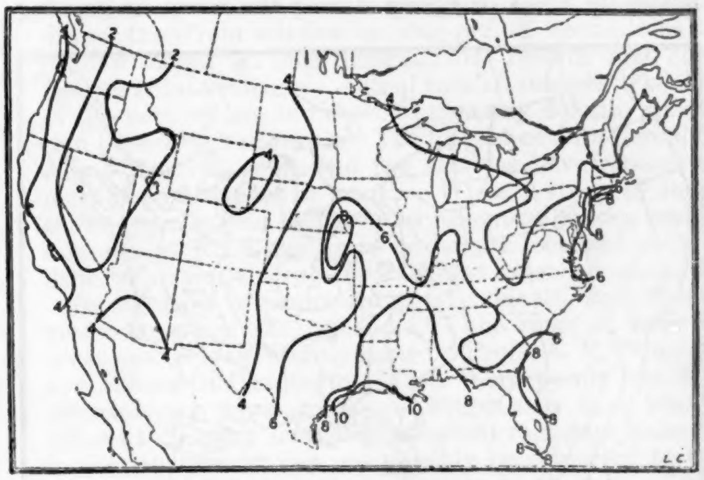

FIG. 15.—Maximum precipitation in 24 hours.

In some isolated cases, much heavier rainfall than is indicated on figure 15 has been recorded for 24 hours at substations of the Weather Bureau, particularly where topographic features of the immediate locality are such as to facilitate condensation and precipitation under favorable meteorological conditions. However, the chart affords a general picture of the maximum precipitation in 24 hours during the period covered, as it is drawn to the records of all regular reporting stations.

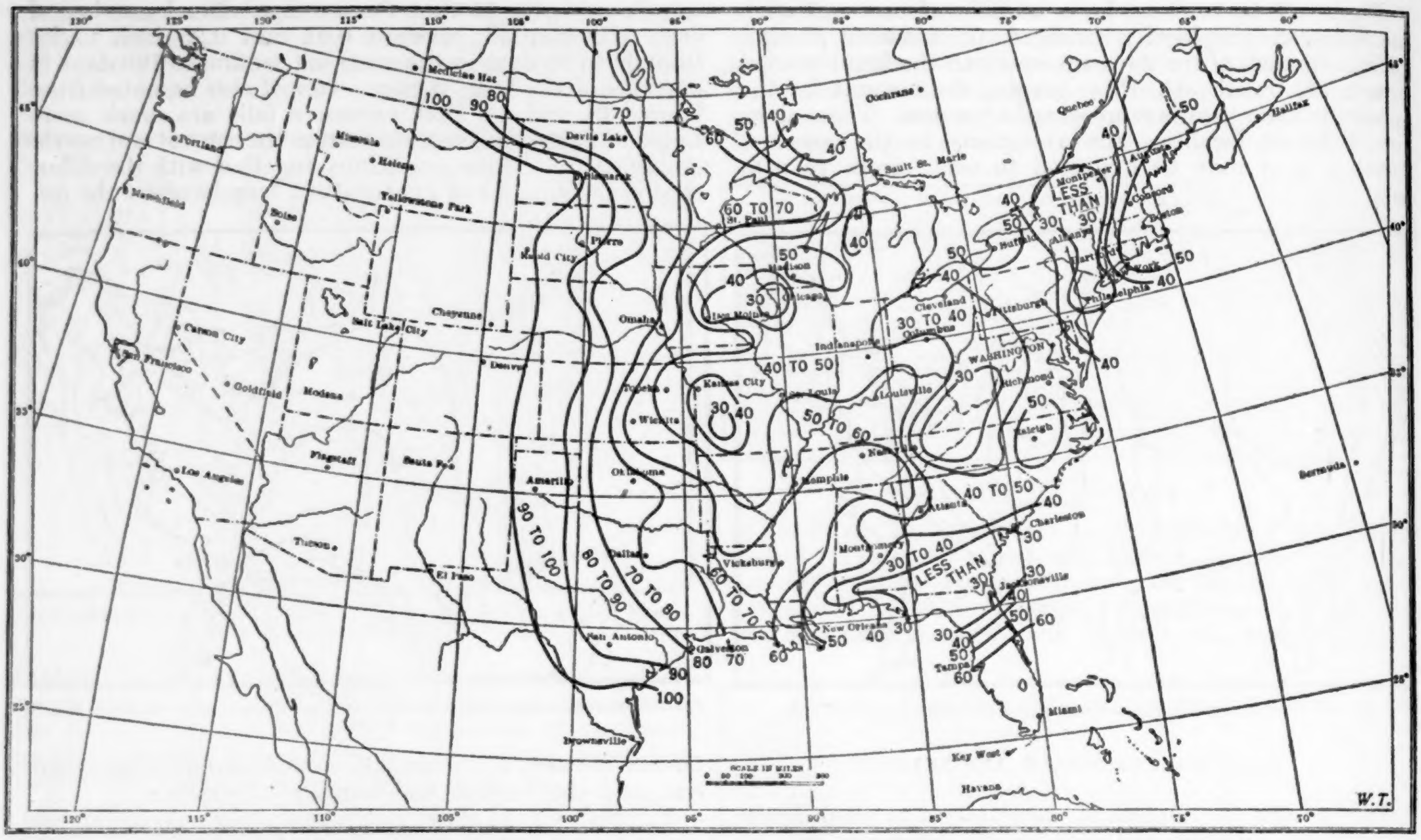

FIG. 16.—Greatest number of consecutive days without 0.25 inch of rainfall from March 1 to September 30, for the 20-year period, 1895-1914.

SUBNORMAL RAINFALL.

In addition to the frequency and intensity of rainfall, it is important in considering charts of average precipitation to take into account the frequency of subnormal rainfall, or droughts, in different sections of the country, especially those occurring during the warm or growing season in areas where rainfall is usually adequate for vegetation. Figures 16 and 17 show some interesting phases of subnormal rainfall for the country east of the Rocky Mountains. The first named indicates the percentage of years with 30 consecutive days, or more, without 0.25 inch of rainfall in 24 hours for the period from March to September, inclusive, and the other shows

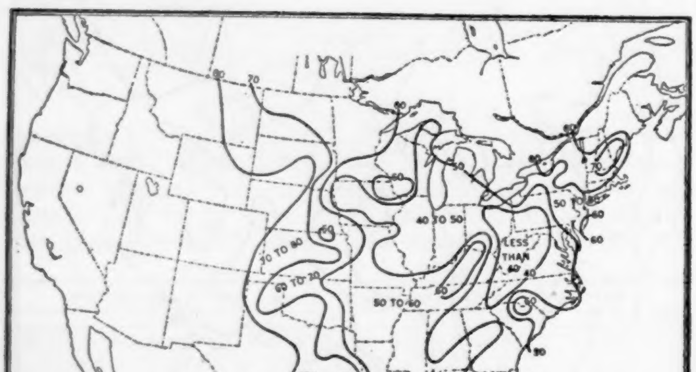

FIG. 17.—Percentage of years with 30 consecutive days or more without 0.25 inch of rainfall in 24 hours from March 1 to September 30, for the 20-year period, 1895-1914.

the longest period in 20 years with similar conditions prevailing. It will be noted from figure 16 that from the central Appalachian Mountain district northward to Lake Erie droughts of this character occur on the average only about 1 year in 3, which is also the case in portions of the Northeast and Southeast, and in limited areas in the lower Missouri and upper Mississippi Valleys. The percentages increase, as a rule, from the Mississippi Valley westward, reaching 75 per cent in the central plains and 100 per cent in the extreme western portion of that area. The longest period in 20 years of consecutive days without 0.25 inch of rainfall in 24 hours ranges from a maximum of about 80 days in the western Great Plains to 40 in the upper Ohio Valley and central Appalachian Mountain districts.

RAINFALL REQUIRED FOR CROP PRODUCTION.

The amount of precipitation required under favorable distribution for the successful production of crops in much of the country east of the Rocky Mountains is considerably less than the average annual amount. It is usually considered that between 15 and 20 inches of annual precipitation, broadly speaking, determines the dividing line between areas where farming operations can be successfully conducted by ordinary methods and those where irrigation or other special methods are necessary; no hard and fast rule can be laid down in this connection, however. There are, in some northwestern States, important grain areas which receive, on the average, less than 15 inches of precipitation annually; in fact, wheat is grown in some places in that area where the average annual amount is only about 9 inches, but in such cases special care is given to conservation of moisture.

Again, amounts of precipitation as large as those shown on average precipitation charts occur usually in less than half of the years, particularly in the case of monthly values; the amounts in 25 per cent of the years for the several months of the growing season in some of the principal agricultural regions are only about half as large as the 20-year average.

SUMMARY.

In conclusion it may be emphasized that, considering the areas covered and their climatic importance, there are three major types of seasonal distribution of precipitation in the United States. These are the Pacific type, with a marked winter concentration; the Plains type, with relatively heavy rainfall in the late spring and early summer; and the Eastern type, with comparatively uniform distribution throughout the year. The Arizona and Florida types are pronounced in character, but the areas covered are comparatively small and consequently their climatic significance is less important. The Sub-Pacific type is not only less marked in distinguishing features than most of the major types mentioned, but precipitation is scanty throughout the year in much of the area covered by it, which, in considerable sections, precludes extensive crop growth without the employment of special methods of conservation of soil moisture or the artificial application of water to growing vegetation.

SOME CHARACTERISTICS OF THE RAINFALL OF THE UNITED STATES.

By Prof. ROBERT DEC. WARD, Harvard University.

(Abstract from the Scientific Monthly, September, 1919, vol. 9, pp. 210-223.)

Prof. Ward in this interesting and valuable bibliographic paper discusses in considerable detail various phases of rainfall phenomena in the United States. Included in these are the annual and monthly variability; the maximum duration of rainy periods (consecutive days with rain) and of dry periods (consecutive days without rain); droughts; hourly frequency of rainfall; excessive falls; and secular variations in the amount of precipitation.

The importance of a knowledge of the probable limit in the variations from year to year from the average rainfall is emphasized, especially from the standpoint of the farmer and the engineer. It is pointed out that the percentage variations from the mean are larger where the annual amounts are smaller. The following table is presented to show in a general way the ratios of the wettest and driest years to the mean fall:

Mean fall.	Average of wettest year.	Average of driest year.
Inches.	*Per cent.*	*Per cent.*
50-60	142	70
40-50	143	64
30-40	154	64
5-30	178	55

The mean annual variability of rainfall at New York is only 9 per cent, while at San Francisco it is 25 per cent. In addition to the annual variability, Prof. Ward discusses monthly variations and cites some pronounced cases.

The maximum number of consecutive days recorded during the period of record with and without precipitation is a matter of considerable general interest. This, of course, refers to the extreme for the entire period of record and not to the annual occurrences. Over most of the country the longest period of consecutive days with rain ranges from 10 to 20. These conditions are characteristic of most districts east of the Rockies, except in the extreme southern Great Plains. Along the north Pacific coast more than 30 consecutive days with rain have been recorded. From 15 to 30 days have elapsed without precipitation over most of the eastern district and from 30 to 60 days in much of the Great Plains and in the northern plateau and north Pacific Provinces. In the arid southwest over five months have been experienced without precipitation.

Excessive rainfall may result either from short, heavy downpours, or from lighter, but longer continued rainfall. In general, rains of the former type do the most damage, although disastrous floods occasionally result from rainfall of the latter type, particularly when a heavy, warm rain with wind occurs when a deep snow cover is on the ground

As regards the maximum limit of excessive falls, an examination of available data shows that 30 inches of rainfall in a month is not often exceeded, although a maximum of over 70 inches was recorded in a single month at Helen mine, California. The maximum daily fall of record in the United States is 22.22 inches, at Altapass, Mitchell County, N. C., on July 14-15, 1916. Very intensive rainfall, but of short duration, is sometimes experienced. In a record "cloud-burst" at Campo, Calif., August 12, 1891, 11.50 inches of rain fell in 80 minutes, or at the rate of about 8.50 inches in an hour. In some "cloud-bursts" the rate has actually been as high as 16 to 18 inches in an hour, but such intense falls continued for very short periods only.[1]

Popular belief in a "change" of climate goes back to the early decades of the settlement of the United States and frequent mention of the subject occurs in literature. Prof. Ward reviews at some length the available literature dealing with various investigations and conclusions drawn therefrom relative to long-period fluctuations in rainfall, based on both instrumental records and noninstrumental evidence. Actual rainfall records available in this country are too short to give any definite indication of secular variations. The longest cover a period of only about 100 years and few stations have records of more than 50 years in length. While a study of these shows more or less definite and recognizable long-period fluctuations, they appear to be largely localized and no definite conclusions can be drawn for extended areas.

In the case of noninstrumental evidence, such as the measurement of the thickness of the rings of trees of great age, as was recently done by Profs. A. E. Douglass and Ellsworth Huntington, Prof. Ward points out that climatologists agree that such evidence is in a wholly different category from that of actual rain-gage records, in that the former can not possibly be subjected to the same rigid analysis and scrutiny as in the case of the latter. After reviewing the attitude of climatologists regarding noninstrumental evidence of climatic changes, he concludes that the conservative climatologist may well remain open minded on the whole question.

Reviewer's note.—To give some indication of long-period fluctuation in this country, as evidenced by actual gage records, the accompanying graph, figure 1, is pre-

[1] See tables, MONTHLY WEATHER REVIEW, May, 1919, 47.

sented. This shows annual precipitation data for six long-record stations, geographically distributed from east to west across the country. They include data for New Bedford, Mass.; Marietta, Ohio; Oregon, Mo.; Manhattan, Kans.; Boise, Idaho; and Sacramento, Calif. The record for New Bedford covers a period of 100 years, for Marietta 92 years, and for the other stations 50 years each. The heavy horizontal lines shows the average for the entire period in each case, while the vertical bars indicate the respective annual falls. The superposed curves have been smoothed by the formula,

$$(a+4b+6c+4d+e)116=c',$$

ANNUAL PRECIPITATION - LONG RECORD STATIONS

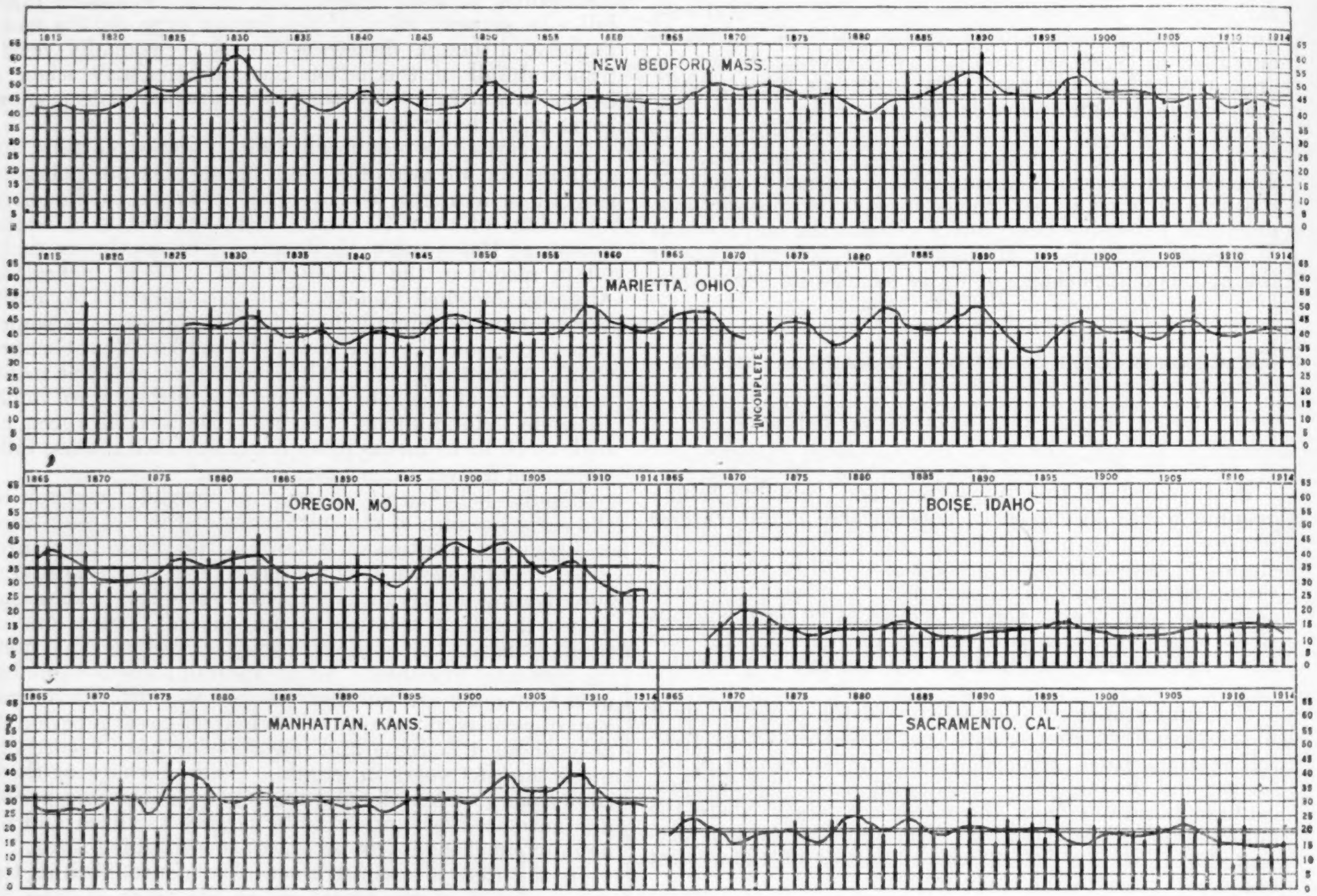

FIG. 1.

where c' is an adjusted average for the middle year of the series. This serves to reduce factors purely temporary and emphasizes tendencies extending over several years. It will be noted that in each of these records there is a pronounced tendency to periods of varying lengths of heavier and lighter rainfall, but no evidence of a permanent increase or decrease appears. Had the records covered several hundred years, however, more definite conclusions could be drawn.—*J. B. Kincer.*

A NEW SEASONAL PRECIPITATION FACTOR OF INTEREST TO GEOGRAPHERS AND AGRICULTURISTS.

By ROLAND M. HARPER.

(Abstracted from *Science*, Aug. 30, 1918, pp. 208-211.)

Instead of resorting to the usual methods of correlating rainfall with soils and vegetation, the author has compared the precipitation April to June, inclusive, with that from August to October, inclusive. These data were prepared for several hundred stations, over a considerable period of time. A map was prepared showing the line of equal rainfall in the two periods, and the departures from this equality. The borders of the United States generally fall in the region of late summer excess, while about three-fourths of the country, including the Mississippi Valley, has an early summer excess. The greatest late summer excess is on the east coast of Florida; the greatest early summer excess occurs in the Black Hills.

There are several interesting correlations suggested by such a map. First, the region of greatest tornado frequency is the region of early summer excess, and that of greatest hurricane frequency is the region of late summer

excess. In the regions where the precipitation is about equal there is little damage from wind. Late summer rains generally come as daytime showers, while early summer rains fall more gently and at night. Thus, while the total seasonal precipitation may be equal in two given regions, the economic effects of the difference in amount between early and late summer [or winter and summer] may be considerable. "A warm rain presumably has a greater leaching effect than cold rain or snow, and regions subject to heavy summer rains, like most of Florida, generally have poorer soils and more swamps than where the summers are dry, as in California." Soil appears to be most fertile where the excess comes in early summer, as is evidenced by the fertility of the Mississippi Valley as contrasted with the less fertile soil of Florida.

"The same precipitation factor seems to control indirectly several economic features. For example, most of the developed water powers in the United States are within two or three hundred miles of the line of equilibrium between early and late summer rains, though this may be chiefly because the same topographic factors that make the water power possible also influence the seasonal rainfall in some way. Some correlations between seasonal rainfall and crops are easily made. Alfalfa, wheat, figs, and upland cotton are not raised much where the late summer rainfall exceeds that of early summer by more than three inches, while sugar cane, pineapples, grapefruit, and sea-island cotton thrive where late summer rains prevail. But, of course, the soil [and temperature] have a great deal to do with this, too."

The further correlation of this precipitation distribution with soil, vegetation, etc., in the other parts of the world on such a basis as this would be of interest. Thus, this line of investigation opens a new and a large field, and it is possible "that by shifting, a little, the periods compared, more significant results can be obtained."—*C. L. M.*

NORMAL PRECIPITATION IN UTAH.

By J. CECIL ALTER, Meteorologist.

[Dated; Weather Bureau, Salt Lake City, Utah, Sept. 13, 1919.]

SYNOPSIS.—The precipitation in Utah as shown by about 180 records of 5 to 49 years' length is least in the depressions and greatest on the higher windward slopes of the mountains generally, the amount being about 10 times greater on the higher mountains than on the depressions to windward. The increase with altitude is about 4 inches per thousand feet on the windward or western slopes and about 5.50 inches per thousand feet on the opposite side of the mountain ranges which intercept storm tracks. A slight decrease is shown near the crests, and the increase begins some distance to windward of the mountains. An important nonconformity appears on slopes which are interrupted by important initial barriers, beyond which there is sometimes a decrease and always a change in the rate of increase. The windward sides of intermediate valleys are drier usually than the leeward sides.

Secular variations in annual and monthly amounts are shown to be without uniformity or reliability. Decade means for every consecutive 10 years in several groups of stations show variations amounting to from 15 per cent to 19 per cent of the 26-year means. The stability of 26-year and longer means is shown to be within 3 per cent the addition of any 10 years' record changing the mean no more than this amount. Certain supposedly wet or dry cycles are shown to be of opposite value or absent from a number of months and stations, and the January to May precipitation is shown to be comparatively stable and subject to less fluctuation. Types of monthly distribution are presented.

INTRODUCTION.

The accompanying chart of average annual precipitation in Utah (chart J.C.A. I) has been prepared from all authentic data available at the close of the year 1918, the records having been adjusted as nearly as possible to the 26-year period, 1893-1918, and the interstation interpolations having been made with every practicable consideration for topographic influences.[1]

The records used have been made principally in the settled communities where cooperative observers were available, at an average altitude of about 5,250 feet above sea level, a figure that has not varied materially through any period of years. The number of stations reporting regularly has been about as follows: 1890, 12; 1895, 25; 1900, 45; 1905, 60; 1910, 75; 1915, 110, and 1918, 125. About 180 localities are represented in all, or nearly one-half the number of post offices in the State. The general average annual precipitation is about one-third as much as in Illinois, the dearth being due to distance from the Pacific Ocean, which is the principal moisture source, and to the interception of the moisture-bearing winds by the coast ranges and Sierra-Cascades. The Wasatch Mountain range forms the principal topographic control of precipitation within the State as it intercepts most of the storm tracks at about right angles; its westerly slopes therefore, as well as the northerly slopes of the Uinta Mountains, receive the State's heaviest precipitation. A comparatively heavy precipitation is also wrested from passing storms by the La Sal and Elk Mountains and their surrounding plateau lands in southeastern Utah.

Contrariwise, the depressions over western Utah which formed the bottom of the prehistoric Lake Bonneville (the Great Salt Lake Desert) is the State's most arid region. The slightly higher plains regions of western Utah generally, from which rise numerous ranges of hills and minor mountains, and the broad basins of the Green and the Colorado Rivers in eastern Utah, are also relatively arid, as a rule.

INCREASE WITH ALTITUDE.

The transition from arid to moist conditions is noticeably more gradual on the windward slopes of the major topographical barriers than on the leeward slopes; the 10-to-15-inch zone (chart J.C.A. I) for instance, being much narrower along the east slope than along the west slope of the Wasatch Mountains. This condition is also rather well-defined in the minor intermediate valleys the western portions of which are usually drier than the eastern portions. These valleys as a whole are successively drier to leeward (eastward) than similar valleys located in the more westerly parts of the broad mountain range in general.

The precipitation increase with altitude begins at a considerable distance to windward of the mountain base, and is progressive at a fairly regular rate on the long gradual uninterrupted slopes, until near the summit where it decreases slightly. The geographical area of diminished precipitation, however, is naturally limited and of reduced consequence. The precipitation on the western slope of the Wasatch Mountains at from 7,500 to 8,750 feet altitude is about ten times the amount over the salt deserts 60 to 75 miles to windward.

Compilations of data depicting the increase of precipitation with altitude on the western slope of the Wasatch Mountains for practically all groups of adjacent stations

[1] The author acknowledges the valuable assistance of Mr. C. F. Korstian, forest examiner, in charge of Research, District No. 4, U. S. Forest Service, Ogden, Utah.

with simultaneous records have been made, many of which are shown in Table 1. Generally the altitude-increase relation is found to be rather irregular, varying with the local topography, though on gradual slopes without important interruptions in topography, the increase is strikingly uniform.

An average or composite graph is presented herewith (fig. 1) which represents an assumed slope (having its nearest counterpart in Salt Lake County from Saltair to Silver Lake) rising from a station situated 10 miles west of the base of the mountain at an altitude of 4,250

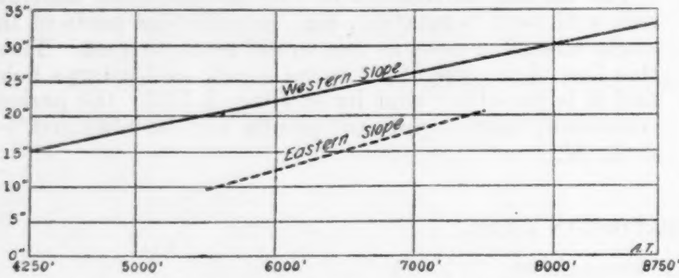

FIG. 1.—Precipitation increase with altitude.

feet, to a station 30 miles to leeward at an altitude of 8,750 feet, within 5 miles distance and 1,250 feet altitude of the general crest line.

From the original graphs and some of the tables herewith it is evident that the decrease in precipitation near the crest occurs within the last 1,250 feet as a rule, though there is not sufficient data at hand to establish either

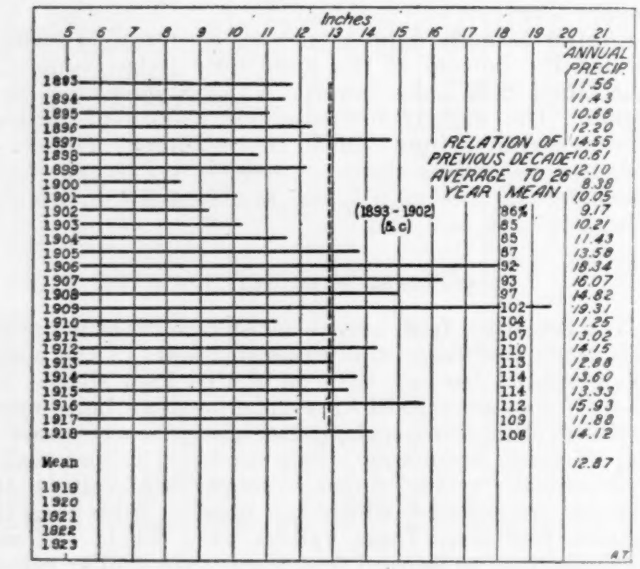

FIG. 2.—Average precipitation in Utah and variation of decade means, in percentages of the 26-year mean.

this recurve on the graph or the initial curve at the base in true proportions. In all groups of adjacent stations where the higher stations are situated to the lee of the initial ridge or barrier of the mountain range an important nonconformity appears in the graphs. (Table 1, I and J.)

The composite altitude-increase graph herewith (fig. 1), shows an increase of precipitation of from 15 inches annually at the lower station to 33 inches at the higher station, or uniformly 4 inches per year for each thousand feet.

Attempts to determine the elements of the counterpart of this graph on the leeward slope of the mountains have been partially defeated through the lack of stations and data, though it is very nearly 5.50 inches per thousand feet on an assumed or composite slope (having its nearest counterpart in Wasatch and Duchesne Counties from Duchesne to East Portal stations) running from a base station at 5,500 feet elevation with 9.50 inches annual precipitation to a station within 1,000 feet of the crest at 7,500 feet altitude with about 20.5 inches precipitation, the stations being about 36 miles apart. The values on this eastern-slope graph are about 55 per cent of the values on the western-slope graph, being about 45 per cent at 5,500 feet altitude and 65 per cent at 7,500 feet altitude.

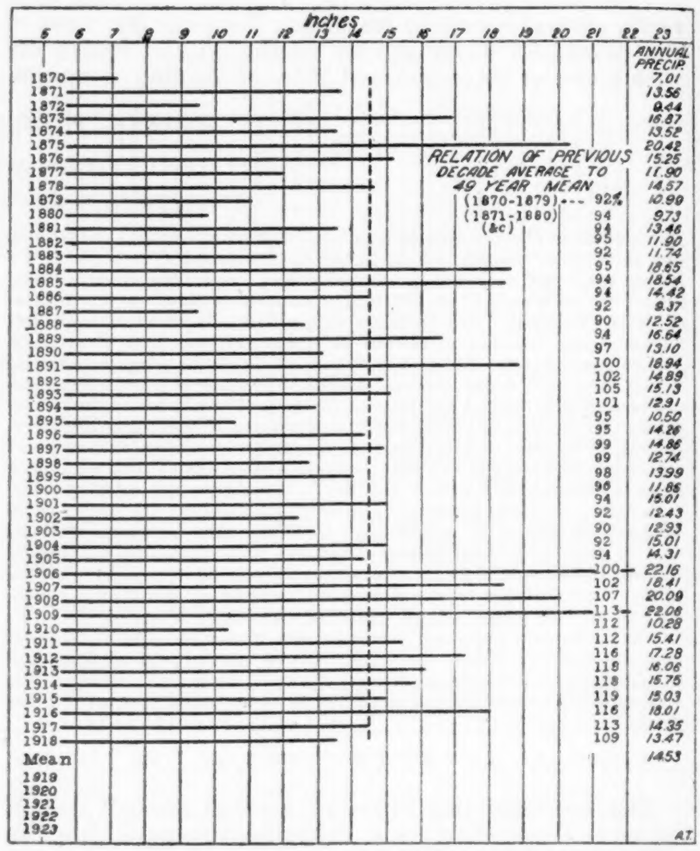

FIG. 3.—Average annual precipitation at Corinne, Ogden, and Salt Lake City combined, showing fluctuation of annual amounts, and variation of the decade means.

The precipitation decreases rapidly immediately to the lee of the summit as compared with amounts to the west of the crest (Table 1, G and H) as shown at the two portals of Strawberry tunnel (United States Reclamation Service) 4 miles apart, between which the Wasatch crest rises about 900 feet above the tunnel; and at Scofield which is about 7 miles to the lee of the summit and about 1,500 feet lower.

An anomaly seems manifested in the diminishing amount with increase in altitude in southeastern Utah County (Table 1, J) but while there is some doubt as to part of the early records at Thistle and Soldier Summit it will be noted that the initial topographic barrier is an important one and is between Provo and Thistle, the large influence of which is apparent in the shorter records at Maplewood and Spanish Fork (near). The effect of the initial barrier is also manifested in Weber, Morgan

and Summit Counties (Table 1, I). In Table 1, K and L, the initial altitude barrier is in a sense between Provo and Heber, though the main crest of the range is considerably to the east of Heber. The slight decrease at Heber shown in Table 1, L, may be attributable to the nonconformity of a periodic variation.

SECULAR VARIATIONS AND ANNUAL FLUCTUATIONS.

Periodic variations in annual amounts of precipitation appear somewhat irregularly in practically all records of 20 years or more the oscillations being of varying length and value (figs. 2, 3, 4, and 5); and there are variations in crop successes, stream flow and other phenomena to corroborate these cycles; but variations in high-water stages in streams and in the number and volume of seeps and springs, often contradictory, are more frequently the result of grazing, water diversion, or other unnatural conditions and should not erroneously be attributed to precipitation changes.

These cycles, which vary in length and intensity for different localities, are not indications of a permanent climatic change and do not form a trustworthy basis for forecasting. And in adjusting short records to long-term averages at adjacent stations the general topography must be similar, the stations be situated within comparatively short distances, and the period compared be as long as possible. Records of even 10 consecutive years' length may be discrepant from the true normal by 15 per cent or even 20 per cent in extreme cases. (figs. 2, 3, and 4, decade percentages.)

The longest records available in Utah are at Corinne, Ogden and Salt Lake City (fig. 3) in which the fluctuation of the 10-year mean about the 49-year mean is from 90 per cent to 119 per cent, thus emphasizing the necessity for a long term of observations for establishing a true normal. The amounts in the wettest single years in this group are about 147 per cent and the driest year about 47 per cent of the 49-year average. However, the addition of a single year as wet as the wettest or as dry as the driest, changes the mean only 1 per cent; and the addition of 10 years as wet as the wettest decade changes the mean only 3 per cent and the addition of 10 years as dry as the driest decade changes the mean only 1.7 per cent.

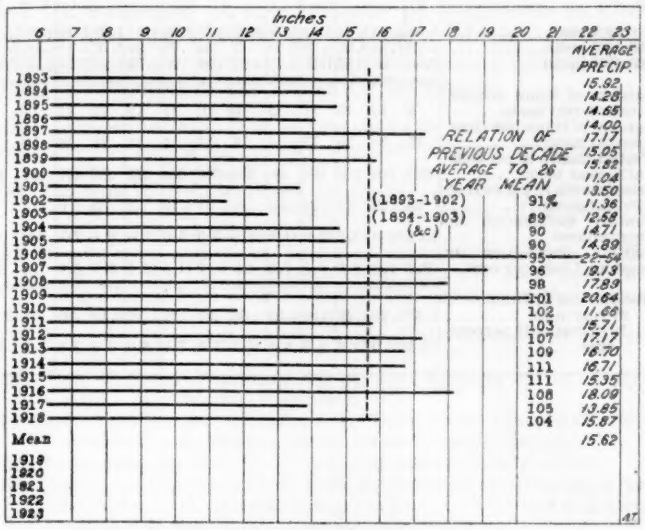

FIG. 4.—Average annual precipitation at Logan, Ogden, Salt Lake City, Heber, Provo, Levan, Fillmore, and Parowan, Utah, combined, showing fluctuation of annual amounts, and variation of the decade means.

The variability of the precipitation in the major agricultural districts of western Utah where long weather records are available is shown in the 8-station group herewith (fig. 4). The 10-year means have fluctuated from 89 per cent to 111 per cent of the 26-year mean. The wettest single year is about 144 per cent and the driest about 71 per cent of the 26-year mean. The addition of a single year as wet as the wettest or as dry as the driest changes this mean less than one-half of 1 per cent; and the addition of 10 years as wet as the wettest decade and as dry as the driest decade changes the mean only about 3 per cent at these stations combined. This 26-year mean is about 105 per cent of a calculated mean for 49 years ending with 1918, as determined by adjustment with the 3-station group (fig. 3).

The uncertainty and irregularity of the periodicity is apparent from an examination of Table 2, wherein the periodicity at Provo and Logan shows a much wider range than at Salt Lake City and Fillmore; and at Levan the periodicity practically disappears. An equally important fact is that the periodicity does not appear uniformly in all the months of the year (Table 3). March and May, whose precipitation is highly important to water users and to nonirrigated vegetation generally shows swings of the precipitation cycle that are opposite in value to those appearing in all other months; and there is practically no variation in the values for November during the supposed wet and dry cycles. Thus, in spite of the invitation in the records themselves in many cases to give credence to these cycles it is safest in general to disregard them.

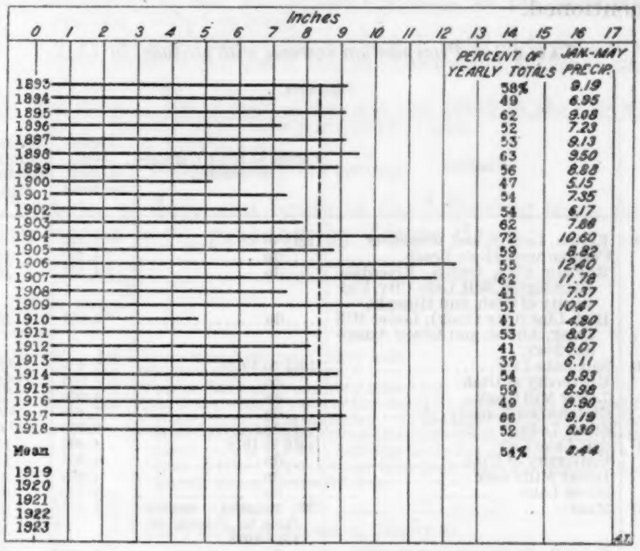

FIG. 5.—Seasonal precipitation, January to May, inclusive, at Logan, Ogden, Salt Lake City, Heber, Provo, Levan, Fillmore, and Parowan, combined, and percentage of yearly totals.

A rather large share of the value represented in the monthly means of precipitation is often due to a few isolated downpours of rain of little agricultural or storage importance. Therefore the tendency shown in Table 3, items 4 and 5 (unnumbered) is for the dry months to exceed the wet months in number. This condition is also shown in the records for the State as a whole. The fact is further apparent in the next two items of that table of the relation of the wettest and driest months to the mean values. February, March, April, and December appear to be rather stable in this particular.

It will be noted that 54 per cent of the precipitation comes in the western Utah group from January to May, inclusive (Table 3), this being the season when there is a considerable dependence on the precipitation by agricultural and power interests, owing to the necessity for supplying storage reservoirs and providing snow stores in the mountains for summer stream flow. It also appears (Table 3 and fig. 5) that the precipitation in this season is subject to somewhat less fluctuation than that during other portions of the year and for the year as a whole. The average precipitation for these five months from 1893 to 1905, inclusive (the alleged dry cycle), is 96 per cent and for 1906 to 1918 (the alleged wet cycle) is 104 per cent of the 26-year average, as compared with 91 per cent and 109 per cent for the years as a whole in the same eras.

There are two fairly distinct types of precipitation distribution in the State (Table 3, last three items), the maximum amount in western Utah coming from about January to May, inclusive, and in eastern Utah from July to October, inclusive, though these types are not manifested uniformly in all stations within the areas mentioned.

TABLE 1.—*Precipitation increase with altitude, in Utah.*

(See text.)

	Stations.	Period of record, inclusive dates.	Elevation above sea level.	Average annual precipitation.
A	Kelton, Lemay, and Wendover	1914 to 1918	[2] 4,229	5.21
	Corinne and Saltair Beach	do	[2] 4,230	14.20
	Brigham City, Ogden, Riverdale, Farmington, Salt Lake City, University of Utah, and Midvale.	do	[2] 4,333	16.59
	High Line (City Creek), Lower Mill Creek, Alpine, and Lower American Fork.	do	[2] 5,054	18.82
B	Salt Lake City	1915 to 1918[1]	4,400	[3] 2.98
	University of Utah	do	4,500	[3] 3.48
	Lower Mill Creek	do	4,959	[3] 4.18
	Cottonwood Nursery	do	7,400	[3] 6.28
	Silver Lake	do	8,700	[3] 6.24
C	Salt Lake City	1916 to 1918	4,400	15.30
	University of Utah	do	4,500	15.82
	Lower Mill Creek	do	4,959	22.45
	Silver Lake	do	8,700	40.65
D	Manti	37 months, mostly June to November, 1914–1918.	5,575	[5] 40.01
	Great Basin Experiment Station	do	8,750	[5] 83.80
	Alpine substation	do	10,000	[5] 70.71
E	Spanish Fork	1911 to 1913	4,711	18.21
	Maplewood	do	4,890	19.91
	West Portal [4]	do	7,650	28.40
F	Provo	1909 to 1913	4,532	17.39
	West Portal [4]	do	7,650	28.33
G	West Portal [4]	January, 1912, to September, 1913.	7,650	[5] 50.15
	East Portal [4]	do	7,606	[5] 39.20
H	East Portal [4]	1912 to 1916	7,606	22.54
	Scofield	do	7,625	18.15
I	Ogden	1905 to 1916	4,310	19.77
	Henefer	do	5,301	21.26
	Castle Rock	do	6,240	17.00
J	Provo	11 years [6]	4,532	14.99
	Thistle	do	5,033	13.36
	Soldier Summit	do	7,454	11.68
K	Provo	26 years [6]	4,532	15.31
	Heber	do	5,593	17.27
L	Provo	7 years [6]	4,532	17.70
	Heber	do	5,593	17.12
	East Portal [4]	do	7,606	21.06

[1] June to September, inclusive.
[2] Average elevation.
[3] June to September average.
[4] Strawberry Tunnel.
[5] Total for period indicated in column 2.
[6] Identical years.

TABLE 2.—*Table showing differences between rainfall of two 13-year periods.*

Stations.	1893–1905		1906–1918		26-year mean, 1893–1918.
	Mean.	Per cent of 26-year mean.	Mean.	Per cent of 26-year mean.	
	Inches.		*Inches.*		*Inches.*
Logan	14.20	86	18.89	114	16.54
Ogden	14.00	87	18.25	113	16.12
Salt Lake City	15.20	95	16.95	105	16.08
Heber	16.25	94	18.25	106	17.27
Provo	12.67	83	17.95	117	15.31
Levan	15.75	98	16.24	102	16.00
Fillmore	13.61	95	15.18	105	14.40
Parowan	11.85	90	14.40	109	13.13
8-station mean	14.20	91	17.02	109	15.62

TABLE 3.—*Precipitation periodicity and variability at Logan, Ogden, Salt Lake City, Heber, Provo, Levan, Fillmore, and Parowan, combined, representing the agricultural district of western Utah.*

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
26-year mean	1.64	1.60	1.94	1.50	1.76	0.69	0.76	0.87	1.14	1.31	1.19	1.22	15.62
1893–1905 mean	1.28	1.54	2.01	1.49	1.82	.47	.56	.78	.94	1.07	1.16	1.09	14.21
1906–1918 mean	2.00	1.66	1.87	1.51	1.70	.92	.96	.95	1.34	1.55	1.22	1.35	17.03
Number of times greater than 26-year mean	9	12	10	11	12	10	10	11	12	13	12	14	13
Number of times less than 26-year mean	17	14	16	15	14	16	16	15	14	13	14	12	13
Wettest month in per cent of 26-year mean	210	190	190	192	286	319	246	306	227	266	192	184	144
Driest month in per cent of 26-year mean	38	29	12	24	31	6	24	10	3	5	0	12	71
Monthly distribution in percentages	10.5	10.0	12.5	10.0	11.0	4.5	5.0	5.5	7.0	8.5	7.5	8.0	100
Monthly distribution in eastern Utah, per cent	9.0	7.5	8.5	6.5	7.0	4.5	11.0	11.5	12.5	9.5	5.0	7.5	100
Precipitation in Utah:													
26-year mean	1.37	1.28	1.47	1.09	1.23	.58	.87	.92	1.03	1.10	.95	.98	12.87
Distribution in percentages	10.5	10.0	11.5	8.5	9.5	4.5	7.0	7.0	8.0	8.5	7.5	7.5	100

HISTORICAL DATA ON THE VARIATION OF RAINFALL IN CHILE.

By C. E. P. BROOKS.

[Dated: Meteorological Office, London, Sept. 30, 1919.]

SYNOPSIS.—A book published by B. V. Mackenna in 1877 contains numerous researches into the municipal archives at Santiago. These are summarized, and shown to suggest two periodicities in rainfall: 1. A variable "Brückner period." 2. A period of about 108 years. 3. In addition, the eighteenth century was drier than the nineteenth.

INTRODUCTION.

Recently there has come to my notice an old and apparently little known book, published by B. Vicuña Mackenna at Valparaiso in 1877, and bearing the title "Ensayo Histórico Sobre el Clima del Chile (desde los tiempos prehistóricos hasta el gran temporal de Julio de 1877"). The author appears to have brought to bear a good deal of research into the municipal archives at Santiago and other documents, and in view of the recent work of Prof. Ellsworth Huntington his results are of interest.

Many of the 476 pages which form the book are occupied by accounts of the systems of irrigation in Chile and by the speculative meteorology of the seventies, but the remainder contains much interesting information, which is collected in the following summary:

1520. Discovery of Chile. A drier year than 1536.
1536. Very hot spring and stormy summer, followed by a period of calm and abundance.
1540. Pedro de Valdivia traversed the desert of Atacama with a column of troops and cattle without inconvenience. This period of rain continued till 1544.
1544. Heavy rains and storms in June, "a monstrous thing." "The Indians say that they have never seen any such thing, but have heard from their fathers that in the time of their grandfathers was such another year."
1609. A real flood like that of 1544. Jines de Lillo commenced building river walls.
1618. The Mapocho overflowed its channel because of the copious rains. And this was in *autumn*.
1637–1640. First historic drought. "In these three years (1637-1639) one could not collect a penny [of rent] for the droughts."
1647. Inundation on June 16. The spring was extremely rainy.
1650. (circa). In the second half of the seventeenth century was a continuation of the general drought so that in 1687 "one sold farms which had cost 12,000 pesos for only 250 pesos."
1682–1692. But a flood of the Mapocho tore down some of the walls between 1682 and 1692.
1697. There was a general inundation of the country.
1705. July 6. Public prayer for rain.
1710. Year of drought.
1717. August 6. An act was passed by the corporation of Santiago appointing a water sheriff, to divide the waters of the Mapocho fairly according to area of land. In the same year was first mooted the diverting into the Mapocho of the neighboring river Maipo.
1718. March 6. Another public prayer for rain. The scarcity of water was prolonged until 1722.—
1723. And was followed by a flood in 1723.
1727. Year of drought.
1730. Great earthquake.
1743. Great drought; prayers for rain.
1744. Slight flood and epidemic.
1746. Copious rains.
1748. Great flood (the worst of the eighteenth century except that of 1783). This flood destroyed the river walls of Jines de Lillo (1609) and a bridge of 60 arches built in 1670-1682. The city was completely inundated.
1749. New river walls were commenced.
1751. Terrible earthquake. (The heavy rains appear to have continued until 1761.)
1764. Flood of Gonzaga.
1770. Rained only 112 hours.
1771. A still greater drought. A special meeting of the municipal council ordered prayers for rain.
1772–73. Drought still continued, especially in 1773.
1774. One of the driest years of the century.
1775–77. Continued dry.
1777. June 25. Public prayer for rain ordered. This year was "a veritable furnace."
1779. Agitation to divert waters of River Colorado into Mapocho. May 13. Serious flood inundated the lower part of the city and attacked the walls commenced in 1767.
1781. But save for this flood the drought was prolonged into 1781.
1782. May 2. A prayer for rain was ordered, because there was no water for the vineyards.
1783. April 13. The great flood set in. A heavy trembling, followed by a series of shocks during most of April. May was excessively rainy. On June 3 was an alarming flood of the Mapocho. From June 3 it continued to rain violently and on morning of 16th were completed 209 hours of incessant rain, accompanied by a hurricane from N. On 17th the rain ceased and the flood began to subside.
1784. The drought again set in. The deficiency of water lasted at least until 1791. (Public prayer for rain on June 7.)
1791. Year of drought.
1797. Fields extremely sterile.
1799. Year of drought.
1804–1824. Moderate years with a tendency to scarcity rather than excess of water. 1804 was the driest.
1812. The spring of 1812 was probably stormy, as the barometer reached a very low level.
1817. Was excessively rainy in the south and center of the country. The armies in the War of Independence could not make way for the floods.
1819. Was sterile. Up to June 2 no rain had fallen in the capital. After that till 1822 there was excess of rain.
1822. The spring of 1822 was wet.
1823 and 1824 had comparatively dry springs.

The total of days and hours in the following table are taken from a book, probably by Tomas Reyes:

Year.	Days.	Hours.	Notes.
1824	10	220	There were some very heavy falls.
1825	21	130	The falls were less heavy.
1826	17	147	Year of slight rain; one very heavy fall.
1827	31	300	One of the wettest years of the century. First shower on April 17. Heavy rains began on June 1. On the night of June 5 the barometer reached its lowest since 1812 and a great flood burst over the north part of the city, but this flood was not comparable with that of 1783. At the same time took place the greatest flood known on the Serena till then.
1828	30	280	} Almost as rainy as 1827.
1829	31	320	
1830	17	116	Heavy shower of 10 hours on January 30.
1831	13	150	
1832	......	99	A year of plagues and mortality. On August 12 snow fell heavily.
1833	......	440	Wettest year but one of the series. First shower on April 14.
1834	19	152	Flood on Mapocho in July.
1835	16	118	
1836	......	219	
1837	......	288	First showers in January. Flood on Mapocho in May.
1838	......	156	
1839	......	125	Comparatively dry.
1840	......	153	
1841	......	313	Rain commenced on February 21.
1842	......	171	But heavy rain. A fall of 3 hours in January, then on June 8–11.
1843	41	390	Short shower in January.
1844	......	130	
1845	......	417	Excessively wet, though there were comparatively few rainy days.
1846	......	240	
1847	29	147	
1848	......	111	Alarmingly dry. Great snowfall at Santiago on August 18. Short shower in January.
1849	13	185	
1850	41	285	First shower on March 30. One of the stormiest springs known; great heats, gales, and floods, especially in June; 553 mm. of rain fell at the American Observatory established under Domeyko at Sta. Lucia. This was the last year of observation by days, hours, and minutes.

The average for the whole period was 20 days 215 hours.

1851. Very wet, especially at Coquimbo. The series of wet years lasted till 1860.
1856. Hurricane from North on March 11–13, causing floods in the Serena and Mapocho. At Concepcion the hurricane appeared on the 9th.
1858. Flood.
1863. Very dry and hot. No rain till June 1 and then only a little.
1864. Very stormy. Hurricane in Valparaiso on June 2 to 9. Flood on the Mapocho.

1868. Flood.

1876. A planter kept count of the rain days and hours "as of old." The duration was 26 days and 187 hours. The corresponding rainfall was 215 mm.

1877. Rain began in February (0.38 inch on 9th at Valparaiso). Heavy rain in April; 3 inches in a heavy gale on 25th. May and June were mild, but very heavy rain in July caused floods on all the rivers of Central Chile.

Summing up, the author finds:

1. The climate of Chile is essentially stable.
2. Droughts have occurred at intervals from prehistoric times.
3. Periods of drought were much more prolonged formerly, especially in the eighteenth century, when they sometimes lasted 20 or 30 years, (1705–1723 and 1770–1797); and there were frequent years calamitous for public health and agriculture (1705, 1710, 1717, 1727, 1743, 1770, 1771, 1773, 1777, 1781, 1782, 1784, 1791, 1797, 1799). In the nineteenth century only two years were comparable with these (1832 and 1863).
4. Floods have occurred with a similar periodicity, but much further apart, and sometimes in the middle of a period of drought which they did not seriously modify. They were more frequent in the nineteenth century than in the eighteenth.
5. The rainy years occur almost always in groups, forming more or less long and homogeneous periods of three, five or more years.

To these conclusions I would add:

6. If we tabulate the data we find evidence of a remarkable double periodicity. Taking the wet periods first as being more sharply defined and completing the series from the readings of the rain gage at Santiago, we have:

———	1536–1544	No records.
1609, 1618	1647	1692, 1697
1723	1744–1768	1779–1783
1827–1830	1850–1877	1898–1907

Between 1544 and 1609 there are no climatic data at all, but if we assume that this interval of 66 years was broken by a slight maximum of rainfall in the middle, we have from 1540 to 1904 the crests of 11 waves of rainfall, separated by 10 depressions, giving an average interval of 36 years, which agrees well with Brückner's period. The individual intervals were, in years:

(?) 37, (?) 37, 34, 48, 28, 33, 26, 48, 34, 40.

Further, the middle years of each century appear to have represented the maxima of a major wave of about 108 years (the intervals are 107, 109, 107 years), which agrees closely with periods of between 106 and 111 years advocated by various authors. There is evidence that this period goes back yet another cycle, in the statement referred to 1544; that a similar flood was experienced three generations earlier.

The chief periods of drought show a similar periodicity, but less marked:

———	1637–1640	1650–1687
1705–1722	1743–——	1770–1777
1784–1804	1831–1832	1879–1880
1909–1912	———	———

RAINFALL VARIATIONS.

[Reprinted from Nature (London), May 1, 1919, pp. 177–178.]

At the meeting of the Royal Meteorological Society held on April 16, two papers on variations of rainfall were read.[1] The papers are summarized below.

Mr. A. A. Barnes, in his paper on "Rainfall in England, the true long-average as deduced from symmetry,"[2] stated that it has been usual to assume that the average annual rainfall during any period of 35 years can be adopted for obtaining the "long-average" at any rain gage, but he considers that the fluctuations which occur between such averages for various 35-year periods tend to show that the basis is somewhat uncertain. By an exhaustive analysis of the annual readings at 38 rain gages in England during the 62 years 1856–1917, he shows that variations of as much as 5 per cent. on each side of the mean are quite possible when dealing with successive 35-year periods. From these same records it is then shown that far greater consistency in the value of the average can be obtained by taking periods symmetrical about the end of the year 1886. Both by means of tables and diagrams Mr. Barnes shows that that date is a very critical one in regard to rainfall in England, and that, as a rule, the years before that date were relatively far wetter than years subsequent to it. Hence the balancing of the earlier wet years by the later dry years establishes the principle of symmetry about that date, and it is shown that by this method the maximum departure from normal which results from taking each of the fifteen long periods symmetrical to the end of the year 1886 does not exceed 1 per cent in the case of any of the 38 gages which were examined.

Mr. C. E. P. Brooks's paper was on "The secular variation of rainfall."[3] In order to obtain a measure of the secular variation of rainfall during the past 30 to 50 years, correlation coefficients were worked out between the annual rainfall at each station and "time," the measure of the latter being the number of years before or after the middle year of the series. This was done for 162 stations distributed over the globe, and the results were charted on a map. This map shows that the greater part of the world is divided among a few definite regions of wide extent, in each of which the rainfall has been either increasing or decreasing The most important area of increasing rainfall is temperate Eurasia (except the western seaboard); other areas are southeast South America and the south of Australia. Areas of decrease are the tropical regions as a whole, South Africa, and the west coast of Europe. It is noted that the number of sun-spots, and also that of solar prominences, during the period in question have been decreasing. For a few stations records of longer period are dealt with, giving indications that the results obtained are due to a periodicity of upwards of 50 years.

[1] See Quart. Jour. Roy. Meteorological Soc., July, 1919, vol. 45, pp. 209-227, discussion, pp. 227-232. Abstract in Sci. Abs. Sept. 30, 1919, pp. 418-419.
[2] Idem., pp. 209-232.
[3] Idem., pp. 233-248.

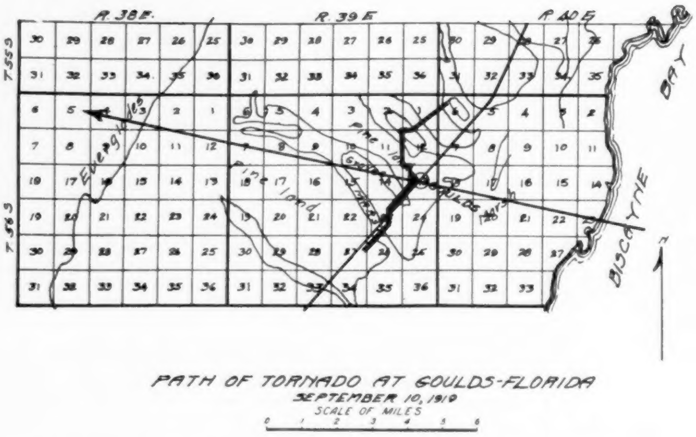

FIG. 1.—Path of tornado at Goulds, Fla., Sept. 10, 1919. (Drawn by Biscayne Engineering Co.)

FIG. 2.

FIG. 3.—Wreckage from tornado at Goulds, Fla.

FIG. 4.—Note pieces of tin roofing wound around trees.

FIG. 5.—Tornado damage about 1 mile west of Goulds.

PAPERS SUPPLEMENTING THE DISCUSSION OF THE WEST INDIAN HURRICANE OF SEPT. 6-14, 1919.

A TORNADO WITHIN A HURRICANE AREA.

By RICHARD W. GRAY, Meteorologist.

A tornado occurred at Goulds, Fla., a small town 20 miles southwest of Miami, on September 10, 1919, between 1:00 p. m. and 1:15 p. m., eastern summer time.

This tornado is of special interest in that it can be said to have occurred within a hurricane area. The severe tropical disturbance that passed through the Florida Straits and, several days later, caused such an appalling loss of life and destruction of property at Corpus Christi, Tex., was central during the afternoon of September 10 over the extreme southeastern Gulf of Mexico. The center of this storm, therefore, was probably within 125 miles of the path of the tornado, and the southern part of the Florida peninsula was still under its influence.

The high winds that prevailed over extreme southern Florida in connection with the tropical storm had diminished by the morning of the 10th, but a moderate gale was still blowing, and the wind continued at this force at Goulds until just before the occurrence of the tornado, when there was a lull for probably 15 minutes.

The tornado developed either over the ocean or Biscayne Bay, and its original form was undoubtedly that of a waterspout. It moved in a west-northwest direction, directly with the strong southeast wind that prevailed at the time on the southeast Florida coast. After leaving the bay, it crossed a 3-mile stretch of marsh land, and there were evidences that this part of the path was extremely narrow. It then entered a pine wood immediately east of Goulds, where the path rapidly widened. At Goulds, the path was about 600 feet in width. After passing over Goulds, the storm moved over a cleared area of about one-half mile in extent, when it entered another pine wood. It is interesting to note that the path through this second wood was 100 feet, or less, in width. The storm continued west-northwest, and was seen to disappear over the Everglades, about 14 miles from the point of entry on the shore of Biscayne Bay. Fig. 1 shows the tornado path.

The tornado was attended by the characteristic pendant cloud, which was described by several persons as having a waving motion, with the detached end apparently moving through a space of 100 feet. It was not accompanied by rain, but the air in the path of the storm was filled with a fine mist.

There were many evidences of the whirling motion of the air. In the first wood through which the storm passed (fig. 2), the uprooted and broken trees apparently fell in all directions. At Goulds, débris from a demolished building was carried across the path of the storm and deposited on the side opposite to which the building stood. A hotel and a large packing house, which were on the northern edge of the path, were lifted from their foundations and moved 15 feet toward the center of the path.

In the second wood (fig. 4), where the path had narrowed to 100 feet, or less, there was no indication of a whirl. All the fallen trees, with one exception, lay with their tops toward the northwest, being practically parallel. One tree which fell toward the southwest was apparently leaning in that direction before the storm occurred. The fallen trees in this narrow part of the path indicated a straight blow, and it was apparently here that the storm developed its greatest force. A dwelling in a small clearing in this wood was completely demolished, and the concrete foundations of the house were pulled out of the ground. Many of the trees had large pieces of tin and sheet-iron roofing wrapped around them, or lodged in their tops (figs. 4 and 5), these pieces of roofing being part of the débris from wrecked buildings at Goulds, about 1 mile to the east.

At Goulds, 19 buildings were damaged and 6 were demolished. Some of the damaged buildings will have to be practically rebuilt. The monetary loss was approximately $25,000.

There was no loss of life in connection with the storm, but five persons were injured by flying débris, and one girl was seriously cut by a piece of flying glass. The absence of fatal accidents was due to the fact that the occupants of all buildings that were demolished heard the approaching storm in time to escape into the open, where they threw themselves upon the ground.

In one instance, five persons escaped injury by taking refuge behind a large boiler. This boiler was struck by pieces of flying timber from the building that had just been vacated.

In another case, a man ran out of the rear of a building just as it was on the point of collapsing. The roof of the building passed over his head, and he was uninjured.

Mr. W. H. Cawley saw the storm approaching, and, getting into his automobile, he started for his home, which is a short distance west of Goulds. He was overtaken by the storm and by flying débris, and a large piece of sheet iron struck the top of the automobile and cut it off, without otherwise damaging the car. Upon arriving home, Mr. Cawley found that his residence was intact, but that his garage, which was within 50 feet of the house, had been demolished.

The post office was one of the buildings completely destroyed, and the postmaster escaped from the building only a few seconds before it was razed. Fortunately, he ran to the rear of a packing house, which, though lifted from its foundations, was not blown down. He was thus protected from flying débris, with which, he states, the air seemed to be filled.

TORNADO NEAR HOBBS, N. MEX., SEPTEMBER 19, 1919.

By E. H. BYERS, Cooperative Observer.

NOTE.—So far as is known this is the first account of a real tornado within the borders of this State. Hobbs is in the extreme southeast border county of the State in a flat, open prairie country.—*C. E. Linney, Section Director.*

About 4 o'clock on the afternoon of the 19th of September, 1919, a small tornado formed south by east of this station (Hobbs, Lea County, N. Mex.), at a distance of about 4 miles. (See map, p. 640.) A shower first formed to the southeast, with a heavy electrical display, strato-cumulus clouds gathering on the extreme west of this formation, in which a funnel-shaped cloud formed and let down from the general level of the surrounding clouds. This funnel pointed westward to where it hit the ground at an angle of about 45°. It traveled over the ground in a direction south of west for a distance of about 1 mile. Fortunately, there were no permanent improvements in its pathway, so that no damage was done, except to destroy some little vegetation which lay in its way. Its course was marked by a column of red dust, which gradually grew thinner, until

it broke about the middle. All this time the thunderstorm was moving northeast, and the appearance was as if the shower drew the tornado apart.

Its pathway was very narrow, probably at no time over 100 yards wide. This storm preceded the night on which occurred one of the most severe electrical storms which this country has ever known, and to the west of this station the heaviest rain they have had in many years, thus completing a very unusual and remarkable 24 hours.

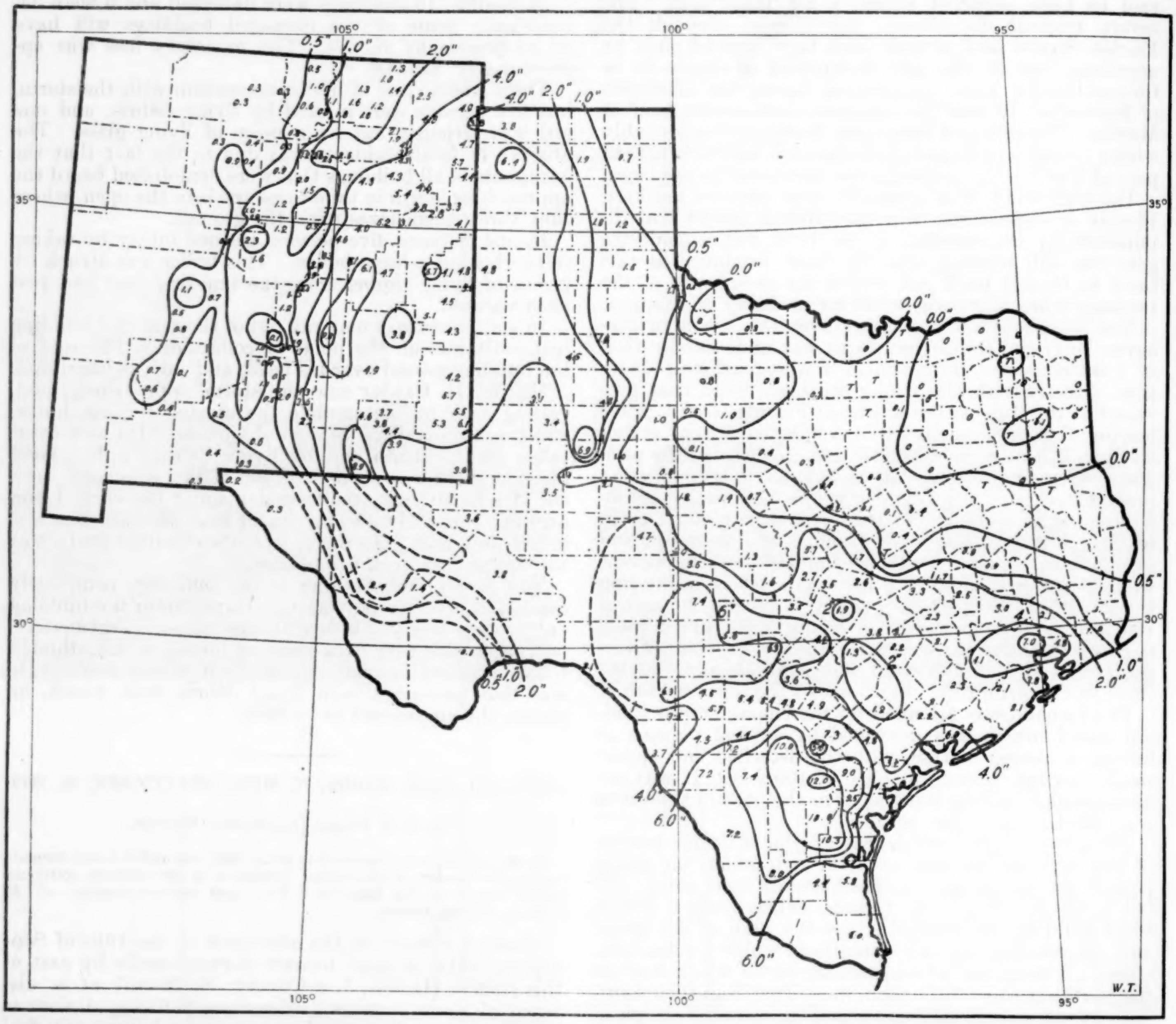

FIG. 1.—Rainfall accompanying the West Indian hurricane Sept. 14-17, 1919. (The short dash in southeastern New Mexico indicates where a tornado occurred.)

HEAVY RAINFALL IN NEW MEXICO SEPTEMBER 14-17, 1919.

The aftermath of the West Indian hurricane, which caused such havoc at Corpus Christi and the immediate Gulf coast on the 14th of September, 1919, was noted as far west as the Rio Grande Valley of New Mexico. Rain began to fall along the southeast border on the night of the 14th, and as far west as the Rio Grande on the afternoon of the 15th, continuing till the forenoon of the 16th in the Rio Grande Valley and until the late night of the 16th from about the one hundred and fifth meridian eastward. The fall in the Rio Grande Valley ranged from about a quarter of an inch to more than an inch, increasing on the eastern slopes of the guarding mountains to more than 2 inches in many localities, but again falling below an inch over the eastern part of the Estancia Valley and the Tularosa Basin. The fall over the southeast mountains and generally to the east of the central mountain areas of the State again increased rapidly to 2, 3, 4, or more inches, with a maximum fall of 9.76 inches at Meek, eastern Lincoln County, while 8.85 inches occurred at the Carson sheep-ranger station, on the eastern slope of the Guadalupe Mountains, western Eddy County. Over the Pecos Valley and the eastern plains 4 to 5 inches occurred, giving, as a whole, the heaviest rainstorm which has visited the State in many years.

Scores of stations recorded excessive precipitation, since most of the downpour occurred on the 15th-16th,

but the measurement of 7.71 inches in 24 hours at Meek is the greatest of record. This occurred from 5 p. m. of the 15th to 5 p. m. of the 16th. The storm beginning at 5 a. m. of the 16th and ending at 11 p. m. of the 16th, gave a measured fall of 9.76 inches for the period, an amount approximating some of the heavy downpours of the Tropics.—*C. E. Linney.*

The accompanying map (fig. 1) shows the distribution of rainfall in Texas as well as New Mexico, September 14–17. For a few coast stations, where rain from the West Indian hurricane began on the 13th, the amounts for this day are included. Where the heaviest winds blew on-shore, the greatest rainfall (12 inches) is a little way inland rather than on the coast, possibly because friction with the land brought the maximum ascensional movement of the air a short distance inland. Another zone of maximum precipitation marks the Edwards Plateau and High Plains.—*C. F. B.*

INFLUENCE OF TROPICAL CYCLONES ON THE WEATHER IN THE VALLEY OF MEXICO.

(By E. Lopez, Bol. Mensual del Observatorio Meteorol. y Seismol. Central de Mexico, 1916, No. 10, pp. 203–206, map. Abstract reprinted from *Geog. Rev.*, June 1918, p. 508.)

From time to time extraordinary rainfalls have been recorded in Mexico City; in September, 1915, for instance, 3½ inches of rain fell in four hours. These are hurricane rains developing in the rear quadrant of the violent tropical cyclone. In the above article, meteorological conditions during eight such storms are shown in tabular form, the paths of the storms being indicated on a map.

EARLY TEXAS COAST STORMS.

(Condensed from the mms. of "Texas Coast Storms," written by Ben C. Stuart and presented to Dr. B. Bunnemeyer of the United States Weather Bureau at Houston, Tex.)

While severe storms swept the coast of Texas long before the dawn of history, the first authentic record we have dates from September 4, 1766, when, according to the Spanish chroniclers, a severe gale visited Galveston Bay. An Indian mission and presidio called San Augustin de Ahumado had been located in what is now Chambers County, and thought to have been situated on or near Lake Charlotte, which connects with the Trinity just north of the present settlement of Wallisville. The wind greatly damaged the mission buildings, and the water from the bay and river submerged the land, which was only a few feet (probably 6 or 8) above ordinary tide. The disaster resulted in the abandonment of the mission. Lake Charlotte is 6 miles from the mouth of the Trinity River, and more than 50 miles from the Gulf of Mexico. The same spot was submerged during the hurricane of August 16–17, 1915.

As the coast of Texas was uninhabited for many years, save by roving bands of savages—the Opelousas, near Sabine Lake and along Bolivar Peninsula, and the Carancahuas and Cokes from Galveston Island as far west as Aransas, and possibly to the vicinity of the Rio Grande—there is no record of hurricanes until the occupation of Galveston Island by Lafitte in 1817, and the earliest report of one comes from statements made by James Campbell, who was in the service of Lafitte and Col. Warren D. C. Hall, an officer under Gen. James Long, who was operating against the Spaniards, and who visited Galveston Island to attempt to enlist Lafitte in the enterprise, but without success. According to them the island was visited by a severe hurricane, the wind being from the east and northeast, and veering to the northwest. The exact date of the storm has not been preserved, but it was in September or October, 1818. The entire island was submerged, with the exception of a small spot on the east end, near the present site of the State Medical College. Lafitte's huts on shore were badly damaged, and several of the vessels cast ashore or sunk. There is no record of the number of lives lost, if any.

From 1820 to 1836 there was no settlement on Galveston Island, although the Mexicans had built a small frame structure there in 1831 for a customhouse, but it does not appear to have been used for any length of time. In 1821 settlers began to arrive, passing up the bay, and located in the succeeding years at Harrisburg, Anahuac, and other points, but in none of the many records of the period from 1821 to 1836 is there mention of any destructive hurricane on the Texas gulf coast. This does not signify that there was none, but as all of the settlements, with very few exceptions, were inland, they would not have felt the effects of one to the same extent as the islands.

The year 1837 witnessed the beginning of Galveston, and by October, several buildings were under construction. Immigrants were coming in, and there were 20 vessels in the harbor. There were no wharves, and the Mexican customhouse was the only building on the island, the population being sheltered in tents and sod huts. On the 1st of October an easterly gale began blowing and continued with more or less intensity until the 6th, causing a very high tide and submerging most of the island. The wind then suddenly veered to the northwest and swept the waters of the bay down upon and across the island. The following account is extracted from the Telegraph and Texas Register (the first paper printed at Houston) of October 11, 1837:

> The late accounts from the seaboard are of the most distressing character. A tremendous gale appears to have swept the whole line of the coast and destroyed an immense amount of property It commenced on the 1st and increased in violence until the 6th. At Velasco four houses were blown down; the whole country for miles around inundated and all of the vessels in the harbor, consisting of the brig *Sam Houston*, and the schooners *DeKalb*, *Fannin*, *Texas*, and *Caldwell*, were driven ashore; the last named has since been got off and cleared on Sunday last for New Orleans. At Galveston the waters were driven in with such violence that they rose 6 or 7 feet higher than ordinary spring tide. They inundated a large portion of the east end of the island and compelled the soldiers of the garrison to desert their barracks, and seek shelter on the elevated ground near the intended site of Galveston City. The large new warehouse of Mr. McKinney and the new customhouse were completely destroyed and the goods scattered over the island. The brigs *Perseverance*, *Jane*, and *Elbe* were driven ashore, and are complete wrecks; the *Phoenix* is also ashore, but slightly injured, and may be easily set afloat again. The schooners *Select*, *Henry*, *Star*, *Lady of the Lake*, and the prize schooner *Correo*, are ashore, some of them high and dry. The *Tom Toby* (privateer) is a wreck, and the *Brutus* (Texan naval schooner) is considerably damaged. The schooner *Helen* is the only vessel which has received no damage. So far as we have been able to learn only two individuals have perished. The history of this country contains no record of any hurricane which has equaled this, either in the violence of the storm or the extent of the destruction. There is reason to believe that the destructive influence of this gale has extended gradually over the surface of the Gulf; we therefore apprehend that the next intelligence from the United States and from Mexico will be rife with accounts of disastrous shipwrecks. We sincerely trust, however, that neither the calamities of enemy or friend will equal our own.

Col. Amasa Turner, who was present, wrote as follows:

> There were about 30 vessels in Galveston Harbor when the great storm commenced on October 1, 1837. It began with a wind from the southeast and held to that quarter mostly for three days; then it vereed a little to the east and so continued until the sixth day, filling the bay very full and making a 4-foot rise at Houston. On the evening of the 6th, the wind veered to the northeast and blew very strong. The schooner, *Tom Toby*, a privateer, parted her cable and went ashore on

Virginia Point. About sunset the wind, veering all the time to the north, and, if possible, increasing, brought the large volume of water from the bay on to the island with such force and violence as to sweep everything in its course. On land every house, camp, sod house and inhabited structure was swept away, except the old Mexican custom-house. Only one of the vessels held to its moorings.

On the 5th of October, 1842, another hurricane visited Galveston, but the wind was not so high as in 1837, nor the tide, although much of the town (then lower than at present) was flooded, and considerable damage to goods was sustained. The wooden Episcopal Church, on the southeast corner of Tremont and Winnie Streets was blown from its blocks and badly wrecked. A number of other buildings were damaged and several small structures were demolished. No loss of life in the town was reported.

The great gale of September 16-19, 1854, which swept the Texas coast, did not inflict much damage at Galveston, its greatest force being felt to the westward. Of its effect at Galveston the Civilian and Gazette of September 19 said:

An easterly gale began to blow last Saturday and has continued almost without interruption to the present time. The wind has not been severe, but being from the quarter which always produces the highest tides, the waters of the Gulf and bay have been higher than we recollect since 1842. The floors of a number of stores on the Strand were overflowed during Sunday night, and considerable damage was done to such articles as were deposited on the floor. The little steamer *Nick Hill* was lost off Dollar Point.

The greatest force of this hurricane was felt at the town of Matagorda to the westward of Galveston. Col. R. D. Parks, then residing there, but afterward at Temple, said: "It left a trail of disaster to be recorded in history. Hardly a house was left standing in the townsite or vicinity." Another eyewitness says: "The storm at Matagorda was September 18, 1854. The water from the bay did not come over the town. Two people were killed. The steamer *Kate Ward* and crew were lost in Matagorda Bay—from report it was said at Dog Island."

The great hurricane of August 10, 1856, was felt but little at Galveston, but l'Île Dernière, or Last Island, a summer resort on the Louisiana coast, was engulfed, with the loss of many lives.[1] The steamer *Nautilus*, from Galveston for New Orleans with 30 passengers, however, ran into the gale and foundered, all hands being lost except a Negro man who clung to a bale of cotton and was cast ashore on the Louisiana coast.

In the latter part of September, 1865, a hurricane struck the town of Calcasieu on the west Louisiana coast. The place was inundated and some eight or ten persons perished. As there was neither telegraph nor rail communication with that place, the report was brought to Galveston by the master of a lumber schooner.

On Wednesday, October 2, 1867, a strong easterly gale commenced blowing at Galveston, which shifted to the northeast during the night, and on the morning of the 3d had attained a velocity estimated at between 60 and 70 miles an hour. There was no Weather Bureau and, of course, the figures were guess work. During the morning of the 3d the waters of the Gulf and bay rose rapidly until much of the city was flooded. The water from the north side came nearly up to Church Street at its higher elevation, while from the Gulf side it reached nearly to Broadway. The cemeteries at Fortieth Street and Broadway were inundated, and all the lowland down the island was covered with water. Much damage was done to buildings in the city and more than 30 were destroyed. The lower floors of the stores on the Strand and Mechanic Street were flooded and their contents badly damaged. The brig *Ocean Wave*, from Philadelphia, was cast ashore on the beach near the present site of Fort Crockett, and her captain drowned. The bark *Palace* and the brig *Egarita* in the harbor were driven ashore, as were a number of small craft, and the steamboats *Alice M* and *Sunflower* were wrecked. The trestle of the Galveston, Houston & Henderson Railroad between Eagle Grove and Virginia Point was completely wrecked, and communication was kept up by means of a ferry boat until it was rebuilt, which was not done for several months. There were three lives lost and the property damage was estimated at $1,000,000, including that to vessels. As previously stated, the gale began from the eastward on October 2, the wind veering to the northeast during the night, and continuing from that quarter until about 2:30 on the afternoon of the 3d, when it lulled temporarily, to veer to the northwest from which point it blew strongly for a short time, the waters receding rapidly, and by 5 o'clock the sky was clear and the wind of only moderate velocity. This hurricane cut a channel 5 feet deep through the low sand flat east of Sixth Street, from the bay to the Gulf, which remained open for only a few months. It also did much damage at the mouth of the Rio Grande and at Brownsville.

NOTE.—The next record I have is of the hurricanes of June 9 and October 1, 1871, but, as the Weather Bureau was then in operation at Galveston, they are omitted.

[1] The tragic story of this disaster has been told with marvelous skill by Lafcadio Hearn in his "Chita, a memory of Last Island."—C. F. T.

THE "QUANTICO" OR CHRISTMAS TYPHOON OF 1918.

By the REV. JOSÉ CORONAS, S. J.

The track of this typhoon is said to be altogether abnormal, a warning for both the seaman and the forecaster. The typhoon is shown to have first moved toward the west by north, then to have inclined northwards whilst to the east of the central part of the Philippines, and finally recurving backward not only to west by north, but to west by south, and even to west-south-west. The slow movement of the typhoon on December 23-24 is said in 99 per cent of the cases to be a sign that the typhoon was recurving north-eastward, especially at the end of December, and to the east of the Philippines. Observations, however, prove most conclusively that the movement was in the opposite direction. The rate of progress of the typhoon was at first about 11 miles an hour, the rate afterwards decreasing to 4 miles an hour or less, whilst after recurving to the west-south-west the typhoon attained its former rate of progress. The vortical calm was probably 15-25 miles in diameter. The area of destruction whilst it was raging in or near Luzon was about 80-100 miles in diameter. A large steamer, *Quantico*, was totally wrecked.[1]—*From abstract in Nature (London), Sept. 25, 1919, p. 79.*

[1] Other typhoons are mentioned on p. 660, below.

THE TRAVEL OF CIRCULAR DEPRESSIONS AND TORNADOES AND THE RELATION OF PRESSURE TO WIND FOR CIRCULAR ISOBARS.

By Sir NAPIER SHAW.

This memoir is a continuation of the study of traveling cyclonic depressions which was begun in the Life History of Surface Air Currents (M. O. 174), published in 1906. Those who are accustomed to study weather maps have generally formed the idea that the typical cyclonic depression which is represented by a group of concentric circular isobars on the map is the base of a column of air whirling about an axis and traveling over the country. Without any special examination of the question the foot of the axis of the whirl has been supposed to be the center of the circle of isobars, and the moving column has been supposed to be fed on all sides by air moving along spiral curves to the axis. These views as applied to traveling depressions, are really erroneous.

It was shown in the Life History that in actual cases the air was fed into the cyclone on the right front, and, as a rule, in spite of appearance, did not reach the axis in the end, but was thrown out again from the rear of the cyclone on the same side, so that the apparent inward spiral movement was in those cases simply deceptive.

The new investigation began by pointing out that there might be cases of revolving columns of air traveling over the country, the bases of which were not represented on the map by groups of circular isobars, but by the isobars of "a small secondary." The destructive small secondary of March 24, 1895, was identified as an example. The tornado in South Wales on October 27, 1913, was cited as another example, and it was generally concluded that traveling revolving columns of air were to be found as secondaries mainly in the southern parts of great cyclonic depressions, not at the centers of those depressions. The primary depression was thought to represent motion of a different kind. These conclusions were set out in a paper on Revolving Fluid in the Atmosphere before the Royal Society in June, 1917.

The present memoir recapitulates that paper and carries the study further by calling attention to certain propositions applicable to the case of what is called the "normal cyclone"; that is, one in which the velocity in rotation is proportional to the distance from the axis as it is in the case of a revolving solid. This normal cyclone is supposed to travel with a specified velocity which is provided for by the proper adjustment of the distribution of pressure.

It is explained that what may be called the center of winds, or the "kinematic center" of the motion; that is, the point round which the winds of a map would appear to circulate, is not the center of isobars, but a point some way from that center on the left of its line of motion. The paths of air would be those traced out by points attached to a horizontal circle, which has its center at the true center of permanent rotation (called the tornado center), and which rolls along the path of the kinematic center. The distance apart of the real center of rotation and the apparent or instantaneous center depends on the rate of rotation and the rate of travel: it may be in some cases 60 miles or more.

The center of isobars lies between the other two centers at a position which can also be calculated from the rate of rotation and the rate of travel by allowing for the distribution of pressure corresponding to each. The whole field of pressure will consist of the combination of the circular isobars representing the rotation, with the linear isobars representing a stream of air which would carry the rotating column along. The complete base of the revolving column will include any circular isobars shown on the map on the left-hand side of the path of the center, and a number of additional isobars formed of arcs of circles on the right hand side of the path of the center of the disk or circular base which fill up the area of the disk. Thus a spinning disk of air in a flowing stream of air would give to a map the appearance of winds circulating round a point on the left of its path, and the controlling pressure which would keep the system in being is a set of isobars centered round a different point the actual center of isobars on the map), also on the left. The position of the actual center of the disk itself would not attract attention at all. It would be somewhere in a set of curved isobars; and though its position could be accertained if the rate of travel were known, there is nothing special to mark it on the map.

It is on that account that the true position of the axis of rotation has never been suspected during the 60 years of the study of weather maps, yet the true position is a matter of great importance for the physics and dynamics of traveling cyclones. The physical processes of ascending air, rainfall, and the like should be thought of as referred to the center of the traveling disk, not to the point on the map which for the moment has no velocity; nor to the still more apparent center of isobars.

It is also shown that air in instantaneous rotation round a point will develop a similar circulation at successive points along a line on the map if it is pushed by a uniform field of pressure toward the right of the path which the center has to follow, and this may prove to be the operative cause of the travel of isobars in certain cases. Any group of isobars which (apart from disturbance at the surface) are not in agreement with the actual winds are in a condition to travel like a cyclone, the direction and speed of travel depending upon the divergence between the actual winds and the winds computed from the isobars.—Meteorological Office Circular 25, June 24, 1918.

[1] Geophysical Memoirs, No. 12, British Meteorological Office, 1918, 4°, 44 pp., 5 pl., 2 figs.

THE RELATION OF WIND TO THE DISTRIBUTION OF BAROMETRIC PRESSURE. (MANUAL OF METEOROLOGY, PART IV.)

By Sir NAPIER SHAW.

Sir Napier Shaw's recently published work, on "the Relation of the Wind to the Distribution of Barometric Pressure," which comprises Part IV of a "Manual of Meteorology," is largely a summary of previous efforts and investigations in aerology.[2] In the preface, the author says: "It represents the progress made chiefly by those who have been associated in the work of the Meteorological Office in the past 20 years. * * * Our concern in this work is to present a summary * * * in the most handy form for conveying an idea of the information which is available."

The subject matter of the book proceeds logically from the observation of surface phenomena to those of the upper air, in order to establish, if possible, some relation between these surface phenomena and the processes which are taking place aloft. Particular emphasis is

[1] Cambridge, 1919, 4°, 160 pp., 4 pl.
[2] A review of this work by Gordon Dobson is published in the Quart. Jour. Roy. Meteorological Soc., July, 1919, vol. 45, pp. 262–264.

laid upon the importance of the work of G. I. Taylor[1] in eddy-motion in the atmosphere, and of the value of his coefficient of "eddy conductivity" in meteorological work. Frequent references are made to the work of Dines and Dobson with pilot balloons. In the concluding chapters he deals with the "revolving fluid of the atmosphere." The Meteorological Office has published[2] Sir Napier Shaw's previous work along this line, so that the material presented in the latter portion of the "manual" is a résumé of that to be found in the memoir.[3] —*C. L. M.*

THE TRAVELING CYCLONE.

By the late LORD RAYLEIGH.

(The London, Edinburgh, and Dublin, Phil. Mag., and Jour. of Sci., 6th Ser., No. 225, September, 1919, pp. 420-424.)

One of the most important questions in meteorology is the constitution of the traveling cyclone, for cyclones usually travel. Sir N. Shaw[4] says that "a velocity of 20 meters/second (44 miles per hour) for the center of a cyclonic depression is large but not unknown; a velocity of less than 10 meters/second may be regarded as smaller than the average. A tropical revolving storm usually travels at about 4 meters/second." He treats in detail the comparatively simple case where the motion (relative to the ground) is that of a solid body, whether a simple rotation, or such a rotation combined with a uniform translation; and he draws important conclusions which must find approximate application to traveling cyclones in general. One objection to regarding this case as typical is that, unless the rotating area is infinite, a discontinuity is involved at the distance from the center where it terminates. A more general treatment is desirable, which shall allow us to suppose a gradual falling off of rotation as the distance from the center increases; and I propose to take up the general problem in two dimensions, starting from the usual Eulerian equations as referred to uniformly rotating axes.[5]

Sir J. Larmor has added to Rayleigh's incomplete article a paraphrase, which closes as follows: "In any case, internal viscosity is negligible in meteorological problems. It is the friction against land or ocean, introducing turbulence which spreads upward, that disturbs and ultimately destroys the cyclonic system; and the high degree of permanence of the type of motion seems to permit that also to be left out of account. As remarked in the postscript, the changes of pressure arising from convection involve changes of density, which will modify the motion but perhaps slightly. There does not seem to be definite discordance with Dr. Jeffreys's detailed discussion."

ON TRAVELING ATMOSPHERIC DISTURBANCES.[6]

By HAROLD JEFFREYS.

[Author's summary.]

The geostrophic[7] relation between the wind and the surface pressure gradients is incapable of accounting for any variation whatever with time in the pressure distribution. All changes in this arise from those terms in the equations of motion that are neglected when the geostrophic relation is assumed. When these terms, which depend on the squares and differential coefficients of the velocities, are taken into account, it is found that an asymmetrical cyclone can move. It seems, however, from the low speed of travel of these depressions, that a simple superposition of a general pressure gradient on a rotating system must be compensated internally in some way, so as to reduce the asymmetry introduced. Thus the remarkable circularity of the isobars in a cyclone is seen to be a condition of its slow movement. It is indicated that the cyclone itself is a very special type of disturbance, in which the pressure, temperature, and velocity are so distributed as to make the wave tending to readjust it travel with extreme slowness; other types of disturbance spread out much more rapidly (with velocities of the order of that of sound) and are dissipated, and this fact is probably the reason why, [that] of all the irregularities possible, the cyclone is the most conspicuous, other forms dissipating before they can be observed.

CHARACTERISTICS OF THE FREE ATMOSPHERE.[1]

By W. H. DINES, F. R. S.

(Abstract.)

SYNOPSIS.—"This report was prepared in 1916, but on account of the war it was not then published." The subject is discussed under the following headings:

1. Methods and places of observation.
2. Amount and reliability of the material.
3. Mean temperatures and gradients.
4. The seasonal variation.
5. The daily temperature range.
6. The humidity.
7. The troposphere and stratosphere.
8. Pressure and density.
9. The motion of the free atmosphere.
10. Statistical data.
11. The connection between pressure and temperature.
12. The vertical temperature gradient and the value of H_e.

Appendix. The standard deviations of the density of the air from 1 to 13 kilometers, and the frequency of occurrence of deviations of given magnitude.

In general the paper deals with data and conclusions that had already been presented elsewhere, but they are here brought together into concise form, together with some of the more recent results. The reader is thus enabled to gain a comprehensive idea of the whole subject without having to consult several separate papers that have appeared from time to time in various publications.

1. *Methods and places of observation.*—For the most part the discussion is based upon results obtained in different parts of Europe, although equatorial and Canadian values are given in some of the tables and are briefly referred to in the text. In all cases the data were obtained by means of sounding and pilot balloons.

2. *Amount and reliability of the material.*—Practically 90 per cent of the balloons sent up in continental Europe are recovered; but in England, owing to the proximity of the sea, the loss averages about 35 per cent. Different sizes of balloons and various types of meteorographs are used, but the mean results of 10 years' work are practically identical. Instrumental and reduction errors are evidently not large, inasmuch as the agreement between near-by stations and between successive observations at the same station is close. All the evidence indicates that the probable error for temperature does not exceed 1° C.; for pressure it is about 4 mb. The effect of the latter in the determination of altitude in the lower levels is inappreciable, but at great heights, e.g., 20 kilometers, an error of 2 kilometers is possible. These errors are largely

[1] Eddy Motion in the Atmosphere, *Phil. Trans.*, 1915, vol. 215, pp. 1-26.
Skin Friction of the Wind on the Earth's Surface, *Proc. Roy. Soc.* Ser. A, 1916, vol. 92, pp. 196-199.
Phenomena Connected with Turbulence in the Lower Atmosphere, idem. 1918, vol. 94, pp. 137-155.
A discussion of these papers by Mr. Eric R. Miller will appear in the October issue of the REVIEW.

[2] Sir Napier Shaw: The Travel of Circular Depressions and Tornadoes and the Relation of Pressure to Wind for Circular Isobars Met. Off. *Geophysical Memoirs*, No. 12-1918.

[3] See Review, p. 643, above.

[4] Manual of Meteorology, Part iv, p. 121, Cambridge, 1919.

[5] Lamb's 'Hydrodynamics, par. 207, 1916.

[6] Phil. Mag., London, January, 1919, Ser. 6, **37**: 1-8. See also Sci. Abs. March, 1919, pp. 92-93.

[7] *Geostrophic.*—"Let us call the one [component] due to the rotation of the earth the 'geostrophic' component, and the other due to the curvature of the path the 'cyclostrophic' component."—Gr. Brit. Met. Office, handbook, Weather Map and Glossary, London, 1918, p. 125.

[1] Geophysical Memoirs No. 13, Meteorological Office, London, 1919,. M. O. 220c, pp. 47-76.

eliminated in the means of a larger number of observations, but, on the other hand, an annual mean, if based on a limited number of records, may be in error a similar amount, since some of the observations themselves may have been made under exceptional conditions.

3. *Mean temperatures and gradients.*—Tables giving mean temperature and gradients show very conclusively the latitudinal variations, viz, lower temperature of the northern stations up to 8 or 10 kilometers and higher temperature above those heights. The following values, taken from the tables, illustrate this variation fairly well, temperatures being expressed in degrees Centigrade absolute:

Height, kilometers.	Petrograd (60° N.).	England, S. E. (52° N.).	Pavia, Italy (45° N.).	Canada (43° N.).	Equatorial.
14	223.5	218.9	217.7	212.5	203
13	23.4	18.7	16.4	14.0	11
12	20.7	18.8	16.1	16.2	19
11	20.0	19.6	18.5	19.3	27
10	21.3	22.2	22.7	23.2	35
9	24.4	27.5	27.3	29.3	43
8	29.8	33.6	33.9	35.9	51
7	37.1	40.7	41.2	43.5	58
6	43.3	47.8	49.4	50.9	65
5	49.8	54.8	56.2	57.7	72
4	55.7	61.7	62.9	64.1	79
3	61.3	67.7	69.2	69.6	85
2	66.7	73.2	75.1	74.8	90
1	71.0	78.0	80.7	78.3	95
0	76.1	(83.0)	....	....	300

In Europe the temperatures do not change on the average above 14 kilometers, but those in the equatorial regions continue to decrease to 17 or 18 kilometers, reaching at those heights a value of about 193° A.

4. *The seasonal variation.*—In determining the monthly mean values for England it was thought best, owing to the small number of observations in each month, to smooth the values by harmonic analysis. It is not certain that the temperatures in the upper air follow the course prescribed by a single sine curve, but until many more observations are available it is quite impossible to compute the amplitudes of the second, third, etc., terms. When smoothed and tabulated, the results show that the annual range extends to 8 or 9 kilometers, but diminishes to about half its surface value at 12 kilometers and above. The extremes occur considerably later with increasing height up to about 11 kilometers but fall back rapidly, the minimum at 13 kilometers and higher levels in Europe occurring near the beginning of the year. In Canada the minimum appears to occur in summer, although observations are not sufficiently numerous to make this a certainty. Attention is called to the probability that in Europe the indicated annual range is greater than the true range, owing to the effect of insolation on the meteorographs.

5. *The daily temperature range.*—Not much can be said with respect to the diurnal range, but in general the surface type decreases rapidly with height and practically ceases between 1 and 2 kilometers. At higher levels a reversal is shown by observations at Blue Hill and Mount Weather. Investigations elsewhere indicate very small amplitudes and no certainty as to the times of the maximum and minimum.

6. *The humidity.*—Humidity in general increases from the surface to the lower cloud level, about 1 to 2 kilometers, and decreases above. Inversions of temperature are usually accompanied by low relative humidity. Low humidity is likewise shown at great heights, but the effect of extreme cold on the hair hygrometer renders such observations of doubtful value.

7. *The troposphere and stratosphere.*—Mean temperatures erroneously indicate a gradual transition from the troposphere to the stratosphere, but in individual observations there is usually an abrupt break. Occasionally, however, the gradient ceases gradually and in such cases the height of the base of the stratosphere, H_c or "tropopause," is taken as that above which the change is not greater than 2° C. per kilometer. In the troposphere inversions are frequent near the surface, especially on clear nights and during the entire day in winter anticyclonic weather. They also occur at the upper surface of cloud layers, but are rarely found between 5 and 10 kilometers. In the stratosphere the conditions are practically isothermal. The value of H_c varies in Europe with cyclonic and anticyclonic weather from about 8 to 13 kilometers. There is also a distinct variation with latitude, as shown in the folllowing examples: Petrograd, 9.6 kilometers; England, 10.6; Italy, 11.0; and southern Canada, 11.7. At all places the height is somewhat greater in summer than in winter, although the mean difference is probably less than 1 kilometer.

8. *Pressure and density.*—The author gives tables containing mean annual pressures at different altitudes for a number of places in Europe and for Canada and the Equator; and mean monthly pressures at different heights over England. These pressures have not been directly observed for the various attitudes but have been computed by the hypsometric formula, the temperature correction being determined from the observed mean values. At intermediate altitudes there is a marked variation of mean pressure with latitude, amounting in the Temperate Zone to nearly 1 mb. per degree, the values decreasing, of course, from south to north. At the surface the change with latitude is much smaller. Above 12 kilometers it again diminishes and at 18 to 20 kilometers there is practically no difference between the mean pressure at the Equator and that at latitude 60° N. at least. The annual pressure range is largest at 7 to 10 kilometers, amounting in England to about 18 mb., highest values of course occurring in summer. At 1 kilometer the range is about 6, and at 15 kilometers about 9 mb. A table of densities is also given. These have not been corrected for water vapor, but the error is small up to 1 or 2 kilometers and negligible at higher levels. Mean temperatures, pressures, and densities for England (S. E.), Europe, Canada, and the Equator are contained in the following table:

Height in kilometers.	England (S. E.)			Europe.			Canada.			Equator.		
	T.	P.	D.	T.	P.	D.	T.	P.	D.	T.	P.	D.
	°*A*	*mb.*	*g./m.*³	°*A*	*mb.*	*g./m.*³	°*A*	*mb.*	*g./m.*³	°*A*	*mb.*	*g./m.*³
20	219	55	87	219	55	87	214	54	88	193	53	91
19	219	64	102	219	64	102	215	63	102	193	63	113
18	219	75	119	219	75	119	214	74	121	193	75	135
17	219	88	139	219	88	139	211	87	144	193	90	162
16	219	102	162	219	102	162	211	102	169	195	107	191
15	219	120	191	219	120	191	211	120	198	198	128	225
14	219	140	223	219	140	223	212	142	233	203	152	261
13	219	164	261	219	164	261	214	167	268	211	178	294
12	219	192	305	218	192	307	216	195	314	219	209	331
11	220	224	355	219	225	358	219	228	365	227	244	374
10	222	261	409	222	262	411	223	266	415	235	283	419
9	228	303	463	227	305	467	229	309	470	243	327	469
8	234	352	524	233	353	528	236	358	528	251	376	522
7	241	407	589	241	408	590	243	413	592	258	430	581
6	248	469	658	248	470	661	251	475	662	265	491	645
5	255	538	735	255	538	735	258	543	733	272	558	714
4	262	615	819	261	614	819	264	618	815	279	632	789
3	268	699	909	267	699	913	270	703	905	285	713	871
2	273	795	1,014	272	794	1,017	275	798	1,011	290	803	968
1	278	900	1,128	277	899	1,128	278	903	1,134	295	903	1,067
0	282	1,014	1,253	281	1,014	1,258	282	1,017	1,258	300	1,012	1,174

9. *The motion of the free atmosphere.*—A consideration of the motion of the free atmosphere, as indicated by observations with kites and balloons and by the motion of clouds leads to the following conclusions so far as the temperate zones are concerned:

(1) The wind on the whole increases with increasing height up to the limit of the troposphere, and it falls off rapidly as the common boundary of the stratosphere and troposphere is passed.

(2) The component of the wind from west to east shows a systematic increase with height, until it begins to fall off in the stratosphere, but the south-to-north component shows no such increase.

(3) The geostrophic [gradient] wind is usually reached at a small height, less—that is, than 1 kilometer; above that the wind still veers somewhat as a rule, but at great heights the winds can not be inferred with much certainty from the surface distribution of pressure.

(4) Strong winds from some point between north and south on the western side are occasionally met with at great heights blowing away from the upper part of cyclonic areas.

The first two conclusions are in accord with pressure observations, viz., a decided south to north decrease at intermediate altitudes and practically no change at great heights, 18 to 20 kilometers. The third conclusion is to be expected, since friction due to topographic interferences largely disappears a short distance above the earth's surface. Nothing definite can as yet be said as to wind conditions in the equatorial regions.

10. *Statistical data.*—The close connection existing between certain elements in the free air has led the author to study statistically all available data for Europe and to compute correlation coefficients between the following quantities:

P_0, barometric pressure at M. S. L.
P_1, barometric pressure at 1 kilometer.
P_n, barometric pressure at *n* kilometers.
T_0, temperature at the surface.
T_1, temperature at 1 kilometer.
T_n, temperature at *n* kilometers.
H_c, thickness of the troposphere, or the base of the stratosphere.
T_c, temperature at H_c.
W, west—east component in the wind, west being positive.
S, south—north component in the wind, south being positive.
G_w, west—east component of gradient wind at surface.
G_s, south—north component of gradient wind at surface.
T_m, mean temperature from 1 to 9 kilometers.
V, total water vapor contents of the atmosphere.
T_{0-4}, mean temperature up to 4 kilometers.

The correlation coefficients are given in the following table:

	P_0	P_9	T_m	H_c	T_c	V	T_0	T_{0-4}	T_4	T_8	W	S	G_w	G_s
P_0	.....	0.68	0.47	0.68	−0.52	0.08	0.16	0.34	.....	.....	.....	.....	.....	.....
P_9	0.68	.....	.95	.84	− .47	.....	.28	.....	0.82	.....	.....	.....	.....	.....
T_m	.47	.95	.....	.79	− .37	.....	.....	.....	.....	.....	.....	.....	.....	.....
H_c	.68	.84	.79	.....	− .68	.39	.30	.66	.64	0.74	−0.09	−0.10	0.11	−0.02
T_c	−.52	−.47	−.37	−.68	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
V	.08	.....	.....	.39	.....	.....	.....	.73	.....	.....	.....	.....	.....	.....
T_0	.16	.28	.....	.30	.....	.....	.....	.....	.....	.....	.06	.06	.37	.19
T_{0-4}	.34	.....	.....	.66	.....	.73	.....	.....	.....	.....	.....	.....	.....	.....
T_4	.....	.82	.....	.64	.....	.....	.....	.....	.....	.....	− .08	− .02	.13	.06
T_8	.....	.....	.....	.74	.....	.....	.....	.....	.....	.....	− .03	.03	.10	− .01
W	.....	.....	.....	−.09	.....	.....	.06	.....	−.08	−.03	.....	.....	.....	.....
S	.....	.....	.....	−.10	.....	.....	.06	.....	−.02	.03	.....	.....	.....	.....
G_w	.....	.....	.....	.11	.....	.....	.37	.....	.13	.10	.....	.....	.....	.....
G_s	.....	.....	.....	−.02	.....	.....	.19	.....	.06	−.01	.....	.....	.....	.....

In addition to the above, the following values which can not be conveniently placed in the table are given:

P_9 and			
T_0	0.28	T_{1-5}	.73
T_5	.60	T_2	0.74
T_1	.68	T_3	.82
		T_5	.82

	T_0 and P_0	T_1 and P_1	T_2 and P_2	T_3 and P_3	T_4 and P_4	T_5 and P_5	T_6 and P_6	T_7 and P_7	T_8 and P_8	T_9 and P_9	T_{10} and P_{10}	T_{11} and P_{11}	T_{12} and P_{12}	T_{13} and P_{13}
Jan.-Mar.	−0.02	0.54	0.82	0.79	0.86	0.85	0.84	0.87	0.91	0.81	0.35	−0.32	−0.38	−0.37
Apr.-June	.14	.28	.49	.79	.89	.89	.92	.87	.81	.45	.20	− .12	− .24	− .01
July-Sept.	− .02	.31	.56	.72	.75	.81	.83	.87	.87	.88	.43	− .08	− .41	− .19
Oct.-Dec.	.33	.56	.76	.77	.83	.87	.85	.85	.86	.78	.29	− .24	− .34	− .50
Means	.11	.42	.66	.77	.84	.85	.86	.86	.86	.71	.32	− .19	− .36	− .28

Also—Steepness of barometric gradient and H_c .... −0.22
Barometric rise in past 12 hours and H_c .... − .17

11. *The connection between pressure and temperature.*—The author points out that the probable errors in all these coefficients are small, inasmuch as in nearly every case more than 100 observations have been used. The values bring out very clearly the close connection between P_9, H_c and the temperature at different levels except at the surface; also between P_0 and all temperatures except at the surface, and between pressure and temperature at the same levels between 4 and 8 kilometers. They show moreover that the lower strata are cold in a cyclone and warm in an anticyclone. "As the barometer falls the temperature of the air column from 1 to 9 kilometers falls also, the value of H_c decreases, and the temperature of the upper air from 11 to 20 kilometers rises. As the depression moves away and the barometer rises the lower air column rises in temperature, H_c increases, and the upper air column falls in temperature." Low pressure at the surface remains low, and high pressure at the surface remains high as compared with the normal, up to about 20 kilometers, but the pressure differences fall off from the ground upward, slightly from 2 to 9 kilometers, and rapidly above 10 kilometers. The cold air in the cyclone can not be accounted for by the wind circulation, since the temperature fall begins while the wind up to moderate heights at least is from a southerly direction; nor by radiation, because the observed change in temperature is altogether too great. It must be due then to dynamic cooling, caused to a small extent by the slightly lower pressure itself, but mostly by vertical circulation. That such circulation necessarily exists is evident from the crossing of the isobars by the surface winds. The process by which this cold air ascends is difficult of explanation, but it is shown that, whatever the cause, "this rule is a corollary that follows from the uniformity of pressure at 18 to 20 kilometers." This pressure equality necessitates a uniformity in the mean temperature of the air column from the surface to 20 kilometers in all parts of the earth and under all conditions of weather; and the data obtained show that this uniformity of mean temperature really exists. In other words, when the lower strata are cold, the upper strata are warm, and vice versa. This may explain the lower temperatures at great heights above Canada in summer than in winter, and the excessively low temperatures at high altitudes above the equator.

12. *The vertical temperature gradient and the value of H_c.*—The concluding section of the paper contains a discussion of the relationship between the temperature gradient and the value of H_c. The cause of the observed temperature gradient is ascribed in part to the mixing of the air by the winds, this mixing being balanced by the opposed effect of radiation, and in part to what may be called the "greenhouse effect," i. e., the transmission of solar radiation *through* the air and the absorption of terrestrial radiation *by* the air. Even then it is not plain why the vertical gradient ceases so abruptly. An inspection of the correlation coefficients already given shows a marked connection between H_c and P_9 and between H_c and T_m. By the method of partial correla-

tion it is found that H_c follows the changes of P_9 with great accuracy, no matter what the variation of T_m may be; also that there is little connection between H_c and the water vapor. In other words, "if the air pressure at 9 kilometers is high, then H_c is large; and if the pressure is low, then H_c is small. It is certainly this pressure that matters; other things are of trifling or of no importance in comparison."

An appendix contains a table, with brief introduction of seasonal standard deviations of temperature, pressure, and air density in England (S. E.) from the surface to 13 kilometers.—*W. R. Gregg.*

VERTICAL TEMPERATURE DISTRIBUTION IN THE LOWEST 5 KILOMETERS OF CYCLONES AND ANTICYCLONES.

By WILLIS RAY GREGG, Meteorologist.

[Dated: Weather Bureau, Washington, October 30, 1919.]

It has been conclusively shown, not only in Mr. Dines' paper, a review of which is given above, but also in several others, that in Europe cyclones are colder than anticyclones at all altitudes in the troposphere, except at and near the earth's surface in winter. This condition is not indicated by observations made in the United States, and it is interesting to ascertain, if possible, the reasons for this difference in the two regions. First, though, it may not be amiss to inquire what has heretofore been the basis of classification whereby certain observations have been represented as having been made in cyclones or in anticyclones. Obviously, if the surface pressure has been the only guide, an entirely erroneous conclusion may have been reached, as a preponderance of observations in one quadrant of a cyclone or anticyclone would produce a result in no sense representative of the average conditions in the one system or the other, but rather those of that particular quadrant. Again, we occasionally have low-pressure [1] anticyclones and high-pressure [1] cyclones; if under such conditions the station pressure determined the classification we are likely to include many observations in one class which distinctly belong to the other. The question of the horizontal distance from the center to which the influence of a cyclone or an anticyclone may be said to extend is also a perplexing one. In general it is believed that the classification should be made from a careful inspection of the barometric distribution prevailing in each case, and that only such observations should be included as are well within the influence of the one system or the other, this determination being dependent, therefore, not only upon the station pressure itself, but also upon the character of the pressure gradient and upon the resultant wind conditions. Moreover, the observations should be as evenly distributed as possible among the various quadrants of the two systems, or, if this is impossible, the mean values in the quadrants should be taken, in order that equal weight may be given to each, for it is undoubtedly true, in this country at least, that the influence of a northerly or southerly component in the wind, characteristic of rising and falling pressure, respectively, upon air temperature is greater than that due to dynamic heating or cooling within the pressure systems themselves. This point will be referred to later.

In the table below are presented data based upon observations with kites at Mount Weather, Va., and Drexel, Nebr. The Mount Weather data are taken from the Bulletin of the Mount Weather Observatory, volume 6, part 4; those for Drexel have not yet been published. In all cases the classification has been made as indicated in the preceding paragraph. All quadrants are well represented at Drexel; not so well at Mount Weather, because of its location south of the storm tracks, thus making it impossible to obtain many observations in the northern parts of cyclones. Quadrants are numbered as follows: 1, northeast; 2, northwest; 3, southwest; and 4, southeast.

[1] Relative to normal, not relative to surrounding pressure.

TABLE 1.—*Mean free air temperatures, °C., in cyclones and anticyclones at Mount Weather, Va.*

Altitude above sea level (meters).	Cyclones.					Anticyclones.				
	1	2	3	4	Mean.	1	2	3	4	Mean.
SUMMER.										
526	22.8	20.6	20.9	20.5	21.2	18.1	23.0	20.3	18.9	20.1
1,000	19.9	17.3	18.0	17.8	18.2	15.3	19.3	16.7	15.6	16.7
2,000	14.7	11.3	11.5	11.5	12.2	10.5	13.2	11.5	10.9	11.5
3,000		5.2	5.8	5.6	(6.3)	5.9	8.3	6.8	5.2	6.6
4,000		−1.1	−.3	−2.1	(−.4)	1.3		2.3	0.2	(1.9)
5,000		−7.2	−6.9			−5.1				
WINTER.										
526	−0.4	−1.6	2.3	2.5	0.7	−3.4	−1.1	−3.8	−3.2	−3.6
1,000	−1.3	−4.6	−.8	3.1	−.9	−5.7	−1.1	−3.1	−5.7	−3.9
2,000	−1.5	−6.3	−5.7	−1.1	−3.6	−6.7	−2.4	−1.0	−6.0	−4.0
3,000	−7.4	−9.9	−10.8	−6.5	−8.6	−10.2	−6.6	−5.1	−10.2	−8.0
4,000		−14.1	−15.9	−11.8	(−13.5)	−15.5	−12.0	−10.9	−15.1	−13.4
5,000			−20.0			−23.1	−17.6	−15.7	−24.2	−20.2

TABLE 2.—*Mean free air temperatures, °C., in cyclones and anticyclones at Drexel, Nebr.*

Altitude above sea level (meters).	Cyclones.					Anticyclones.				
	1	2	3	4	Mean.	1	2	3	4	Mean.
SUMMER.										
396	22.9	19.5	21.8	26.2	22.6	16.6	18.2	20.0	17.8	18.2
500	22.1	19.2	21.2	25.6	22.0	16.4	17.6	19.7	17.1	17.7
1,000	19.2	16.3	18.4	22.6	19.1	12.8	14.9	18.7	13.2	14.9
2,000	14.1	9.8	12.2	16.9	13.2	5.5	10.3	14.4	8.2	9.6
3,000	7.9	3.1	5.5	9.4	6.5	−1.1	4.5	8.1	3.3	3.7
4,000	.9	−2.2	−2.0	2.5	−0.2	−3.8	−0.8	1.0	−1.7	−1.3
5,000			−9.4	−3.4	(−6.5)		−6.6		−7.9	(−7.1)
WINTER.										
396	−4.4	−7.4	−3.4	−1.6	−4.2	−11.2	−5.2	−7.3	−11.4	−8.8
500	−5.1	−8.0	−3.8	−1.0	−4.5	−11.3	−4.5	−7.7	−12.0	−8.9
1,000	−3.8	−9.2	−4.6	2.8	−3.7	−9.7	−2.6	−5.8	−12.4	−7.6
2,000	−4.3	−8.7	−5.7	1.9	−4.2	−10.7	−1.8	−4.1	−9.4	−6.5
3,000	−8.6	−12.7	−10.0	−3.7	−8.8	−14.8	−5.9	−7.3	−12.8	−10.2
4,000	−12.7	−16.6	−14.8	−9.8	−13.5	−19.4	−11.6	−11.2	−17.7	−15.0
5,000				−15.3	(−19.1)	−27.1	−17.8		−22.8	(−21.3)

An examination of these two tables shows that both in summer and in winter temperatures at and near the surface are lower in anticyclones than in cyclones, more decidedly so at Drexel than at Mount Weather. At higher levels there is little difference in the values at Mount Weather, and that slight difference is in favor of the "cold cyclone" theory; at Drexel the anticyclone still continues colder than the cyclone, but the difference

is not as large as at the surface. In other words, the lapse rate in anticyclones is smaller than in cyclones, with the result that in the higher levels the values in the two pressure systems are very nearly equal. Whether or not the relation continues at still greater altitudes in this country is a matter yet to be determined by intensive studies of additional sounding balloon observations.

In Europe, as has already been stated, the entire troposphere, except at and near the earth's surface in winter, is considerably colder during low than during high barometric pressure. What is the reason for these differences in the two continents? Surely we can hardly assume that different physical processes are in operation. Is not the reason rather to be sought in the relative effects of *all* the different factors that influence temperature distribution in the free air? I believe this can be shown as follows: The climate of western Europe is essentially marine in character. As such its temperatures are subject to relatively small fluctuations due to the importation of air from adjacent localities under the influence of winds having successively a northerly and a southerly component. The proximity of the Gulf Stream tends further to a spreading out of the latitudinal isotherms, thus adding to the moderating influences of the ocean. The result is that the effects of radiation, pressure, and vertical circulation are so much greater than those due to northerly or southerly winds as to produce what are actually observed, viz, lower temperatures in cyclones than in anticyclones.

The United States, on the other hand, i. e., those portions in which observations have been made, has a typically continental climate, and its temperatures are alternately affected by strong winds from a very cold northerly region and by almost equally strong winds from a very warm southerly region. The fluctuations are large, so large indeed that they tend to mask the effects of the other factors already referred to. That these latter are operating, however, is perhaps indicated by the fact that there is less difference in the temperatures at the upper levels than at the earth's surface; more particularly is this true at Mount Weather, which lies to the south of most pronounced anticyclonic and cyclonic activity; moreover, its proximity to the Atlantic gives it to some extent a marine climate, so far as easterly and southerly winds are concerned.

Another probable contributing cause to the temperature differences in the two continents is the fact that pressure systems in Europe move only about two-thirds as rapidly as do those in the United States. In Europe, therefore, the heating and cooling effects of radiation, vertical circulation, etc., are more pronounced, since they have greater opportunity for development.

A further inspection of Tables 1 and 2 raises the question as to whether it is not more logical to classify the temperatures with respect to the character of the pressure change, falling or rising, rather than to consider the cyclone or the anticyclone as a unit in itself. Thus, it will be observed that the temperatures in quadrants 1 and 4 of cyclones agree closely with those in quadrants 2 and 3 of anticyclones, and vice versa; in other words, that falling pressures, accompanied by southerly winds, have high temperatures; and rising pressures, accompanied by northerly winds, have low temperatures. To illustrate this, the values in Tables 1 and 2 have been regrouped in Table 3.

TABLE 3.—*Mean summer and winter free air temperatures, °C, over falling and rising air pressure, as observed at Mount Weather, Va., and Drexel, Nebr.*

Altitude above sea level (meters).	Summer.		Winter.	
	Falling pressure.	Rising pressure.	Falling pressure.	Rising pressure.
MOUNT WEATHER, VA.				
526	20.9	19.8	− 0.3	1.0
1,000	17.8	16.6	0.0	− 3.8
2,000	12.0	11.1	− 1.6	− 6.2
3,000	6.6	5.6	− 6.4	−10.6
4,000	(0.5)	(0.2)	−12.0	−15.6
5,000		(− 6.1)	(−17.2)	(−22.5)
DREXEL, NEBR.				
396	21.8	18.9	− 4.6	− 8.4
500	21.2	18.5	− 4.6	− 8.8
1,000	18.8	15.2	− 2.4	− 9.0
2,000	13.9	8.9	− 2.1	− 8.6
3,000	7.5	2.7	− 6.4	−12.6
4,000	0.9	− 2.4	−11.3	−17.1
5,000	(− 4.9)	(− 9.2)	(−17.1)	(−23.8)

That the relations shown in this table persist at all altitudes in the troposphere is well shown in figure 33, page 304, Mount Weather Bulletin, vol. 4, part 4. (See also "Introductory Meteorology," fig. 31, p. 47.) In the stratosphere the reverse relations obtain. Both Table 3 and the figure referred to indicate very clearly that, in this country at least, free-air temperature distribution is controlled to a greater extent by the horizontal wind circulation than by purely dynamic agencies within the high or low pressure systems themselves.

In a statistical study of the data obtained at Mount Weather and Drexel, Mr. Wm. S. Cloud, of the Weather Bureau, has computed, among others, the following correlation coefficients:

P_0, barometric pressure at surface.
P_3, barometric pressure at 3 kilometers.
T_0, temperature at surface.
T_3, temperature at 3 kilometers.
S_0, south component in wind at surface.
S_3, south component in wind at 3 kilometers.

	P_0	P_3	T_0	T_3	S_0	S_3
DREXEL.						
P_0			−0.51	−0.40		
P_3				.66		
T_0	−0.51				0.37	
T_3	− .40	0.66				0.40
S_0			.37			
S_3				.40		
MOUNT WEATHER.						
P_0			−0.16	0.13		
P_3				.54		
T_0	−0.16				0.43	
T_3	.13	0.54				
S_0			.43			

These values are based on about 200 observations. They show a definite relationship between the wind direction and temperature at the surface and at 3 km., whereas no such relationship is indicated in Mr. Dines' values for Europe. Moreover, the coefficients for P_0 and T_0 and for P_0 and T_3 at Drexel are opposite in sign to those for Europe, the annual values being −0.51 and −0.40, respectively. In winter they are −0.76 and −0.44.

No such connection appears in the annual means for Mount Weather, but in winter the coefficient between P_0 and T_0 is -0.41. These figures confirm the conclusions already given, viz., that in the United States, particularly in the interior portions, wind direction exerts a greater influence on the air temperatures than does the sea level pressure.

THE ORIGIN OF ANTICYCLONES AND DEPRESSIONS.

By Lieut. JOHN LOGIE.

[Abstracted from Proceedings Royal Society, Edinburgh, 1918, vol. 39, pp. 56-77.][1]

The essential feature of this theory is "that the chief cause of depressions and anticyclones is to be sought in the phenomenon of *radiation;* * * * that cyclones are caused by *cooling,* and anticyclones by *heating* of the air."

That temperature changes lead in turn to pressure changes is, of course, well known; hence, much of the argument in this paper is new only in form. It is also known that clouds modify the effects of insolation in the manner claimed.

The paper is well worth reading for it deals, in the language of thermodynamics, with a contributing factor (and in our opinion only a factor) in the production of cyclones and anticyclones; a problem full of difficulties, and whose solution is urgently needed.—*W. J. H.*

[1] cf. abstract, Sci. Abs., Aug. 31, 1919, p. 361.

GENERAL MOVEMENTS OF THE ATMOSPHERE.

(Discussion.)

In a recent paper[1] H. H. Hildebrandsson has presented the results of an exhaustive study of all available information on the subject of free air wind conditions. This information is based on observations of cloud and volcanic dust movement and on those with kites, pilot and sounding balloons. From the study are drawn certain conclusions, sweeping in character, which appear to be well founded, providing we can accept the data on which they are based as representative of all conditions. They are not representative, however, and the conclusions, at any rate some of them, are therefore not final. Particularly is this true of the conclusion No. 7, which reads: " * * * a direct upper current from the Equator to the poles does not exist, nor a lower current in the opposite direction from the poles to the Equator."

Most unfortunately neither upper clouds nor free balloons can be observed as a rule during conditions in which a southerly component in the upper winds is to be expected because of the existence of low clouds and generally stormy weather. That is to say, when a cyclone is approaching or is passing to the north of a station, upper winds are strong and have a decided southerly component. This condition is found when observations can be made with a cyclone in that position, as is well shown, for example, in figures 41 and 43 of Cave's "The Structure of the Atmosphere in Clear Weather." But in most cases such observations can not be made in the eastern half of a cyclone because of low clouds. The same thing is true of northeasterly and easterly surface winds under the influence of a cyclone approaching from the southwest with an anticyclone to the north or northwest, as shown in figure 47 and discussed on pages 6 and 78 of Cave's work. See also, in this connection, "Rules" 1, 2, and 4 in "The turning of the winds with altitude," MONTHLY WEATHER REVIEW, January, 1918, p. 21. Under such conditions kites can not be flown owing to the existence of a calm stratum between the surface easterly and the upper southwesterly wind, nor can balloons or upper clouds be observed, because of rainy weather or at least dense cloudiness in the lower layers. It follows, then, that undue weight is given to the observations made in the western half of cyclones where a northerly component in the upper winds is to be expected and is usually observed. Yet we find that even when the greater weight is given to observations in the western half of cyclones, still the resultant wind is almost exactly westerly. What would happen if representative observations could be obtained in all parts of cylcones and anticyclones? Most certainly we should find a resultant westerly wind with a small southerly component, probably so small that it would be shown only by the mean of a very large number of observations—observations which unfortunately can not be made, at least with present methods, for the reasons already given.

Practically no free air observations have been made at sea in middle latitudes, the one region where the planetary circulation should find greatest opportunity for unrestricted development. Conditions here can be judged only from the movements of cyclones. These as a rule travel eastnortheastward, and it is generally recognized that on the average they follow the direction of the upper winds. Unless we consider conditions in all parts of the temperate zones, we can draw no final conclusions.

From theroretical considerations it is certainly to be supposed that the prevailing westerlies have in the mean a slight southerly component. As is well known the latitudinal pressure variation at intermediate altitudes, i. e., 5 to 15 kilometers consists of a decrease from the tropics toward the polar regions. The corresponding temperature change is very small, with the result that the air density also decreases poleward. Under ideal conditions the resulting wind would be exactly parallel with the isobars, i. e., west to east. But conditions are never ideal in any part of the atmosphere. At the surface, where friction and other retarding effects are most in evidence, the departure from a gradient wind is exceedingly large. At the higher levels these effects, which include friction, turbulence and viscosity, disappear to a considerable extent, but most assuredly not altogether. If they are still present (and it must be admitted that they are) then the winds must necessarily make a small angle with the iosbars, i. e., the prevailing westerlies at those levels have a slight southerly component.

How does this air return equatorward? In all probability practically all of it does so in the lower 5 kilometers. Here we find a laditudinal variation in pressure and temperature such that the air density decreases from north to south, a condition that favors a slight northerly component on the average in the winds at these levels. The actual transfer is accomplished for the most part in the movements of anticyclones from north to south, especially over the continents. In a relatively short time as much air can be carried southward in this way as is carried northward at higher altitudes in a much longer time, owing to the greater density in the former than in the

[1] Results of some empiric researches as to the general movements of the atmosphere Translation by W. W. Reed. MONTHLY WEATHER REVIEW, June, 1919, 47, pp. 374-389.

latter case. It is important to note in this connection that mass movement, or at any rate wind resultants, rather than relative frequency of different directions should be made the basis of a study of planetary circulation. Cloud observations in general give direction only and do not therefore give us conclusive results. Added to this is the impossibility, as already stated, of observing wind conditions in the higher strata when low clouds are present.—*W. R. Gregg.*

SUPERPOSITION OF AERIAL CURRENTS IN THE PENINSULA OF CAPE VERDE, SENEGAL.

By H. HUBERT.

[Comptes Rendus, 168, pp. 99-102, Jan. 13, 1919.]

In the interior of western Africa, the normal fall of air temperature with increase of altitude occurs, whether the surface wind is the monsoon or the harmattan, but on the Senegal coast this rule is nor followed when the trade wind blows. Observations made there in a hydroplane during October and November, 1918, show that temperature increases with height, either from ground level or from a height up to about 100 meters, until a maximum is reached between 500 and 600 meters, which may be as much as 6° C. above the temperature at ground level. As height still further increases the normal fall of temperature again sets in, so that ground temperatures are again met with at heights of 1,000 to 1,300 meters. Relative humidity near the ground is high, but falls rapidly at about 200 meters, and reaches a minimum where the temperature shows a maximum.

The observations are explained by the superposition in this season of the dry and hot harmattan east wind above the humid, cool, northerly trade-wind, the plane of contact being below 500 meters. It is always possible, however, for the harmattan to descend to the surface, and entirely displace the trade-wind in these months.—*Science Abstracts*, 3, 1919, p. 150.

ABSTRACTS, REVIEWS, AND NOTES.

AMERICAN METEOROLOGICAL SOCIETY.

An American meteorological society will probably be formally organized at St. Louis, December 29. (*Science*, Aug. 22, 1919.) Strange as it may seem, considering the fact that our national weather service was organized half a century ago, there has never been a national meterological society. According to a recent circular, the project is being received with considerable enthusiasm and several hundred people have indicated their desire to join. The objects stated are:

The advancement and diffusion of the knowledge of meteorology and climatology, and the broadening of their applications in public health, agriculture, engineering, aeronautics, industry, and commerce.

To accomplish these aims, membership in the society has been thrown open to all who may be interested; yet provisions planned for the election of eminent meterologists as fellows will insure its standing as a scientific society. Its membership field is the Western Hemisphere, and its hope is cooperation which will bring together the producer, the teacher, and the user of meterological knowledge. It is stated that no attempt will be made at the outset to launch a new meterological publication—only a monthly leaflet of news, notes, queries, etc., is contemplated.—*C. F. B.*

INTERDEPARTMENTAL BOARD ON METEOROLOGY.

The important benefits resulting from the application of meteorological principles in the direction and control of navigation of the air, as also major artillery and other military and naval operations, has led to certain kinds of meteorological work becoming a more or less permanent activity of the War and Navy Departments. This has resulted in numerous informal conferences between representatives of the Weather Bureau and the other departments, and the whole subject has finally been recognized as of such importance as to justify the organization of a more or less permanent interdepartmental board selected to discuss and consider the relative needs of the departments and the arrangement of cooperation and coordination of work to accomplish these results in the most economical and advantageous fashion and in a manner to avoid unnecessary duplication. The board was created by the Secretary of War, acting for and by direction of of the President, and is as follows:

I hereby appoint a board to consider the question of the collection and dissemination of meteorological data and to make recommendations:

Lieut. Col. Horace Hickam, Air Service.
Lieut. Col. W. R. Blair, Signal Corps.
Lieut. Tunis A. M. Craven, U. S. Navy.
Lieut. (junior grade) C. N. Keyser, U. S. Navy.
Prof. Charles F. Marvin, Chief of Weather Bureau.
Mr. R. H. Weightman, Meteorologist, Weather Bureau.

The order further designates Prof. Charles F. Marvin as chairman of the board and provides that meetings shall be held at the office of the Chief of the Weather Bureau and other places at such times as may be designated by the chairman.

But few meetings of the board have been held as yet, but it is obvious that an interdepartmental agency of this character provides for the most effective coordination and cooperation between the departments interested. It is probable, also, that other departments of the Government that are interested in flying, as the Post Office Department, for example, may be requested to designate representatives.

It is expected that important provisions will be made for the enlargement of the meteorological work of the Bureau in the interest of civil and military aeronautics.—*Weather Bureau Topics and Personnel, Sept., 1919.*

UNIFICATION OF THE BRITISH METEOROLOGICAL SERVICES.

By LIEUT. COL. E. GOLD.

[Extracts from Symons's Meteorological Magazine, September, 1919, pp. 86-88.]

A famous general of the Flying Corps once remarked that, whatever may have been his opinion about the policy of the allied supreme command, he was fully convinced that a single meteorological service was the correct policy for the Western Front. Full interallied meteorological unity was never indeed achieved but there was, in the field, a national unity in favorable contrast with the trinities in Paris and London; and there was the closest cooperation between the French, British, and American military meteorological services.

With the end of the war the movement for unity gained power, and now, at last, the British Isles have one meteorological service with an establishment or personnel and equipment more in accordance with the importance of the

science than the prewar establishment, which corsponded rather with the humility induced in its devotees by the study of meteorology.

This unification and expansion means for meteorologists increased opportunities and responsibilities; it does not mean a meteorological millenium in which all difficulties of administration vanish and the secrets of isobaric charts stand revealed.

* * * * *

By the amalgamation of the army, navy, and air force meteorological services with the parent meteorological office,[1] the new service will be able to combine the teachings of meteorological history with the endeavor to secure simplicity and definiteness in meteorological language, codes, and phenomena. But it will also have unparalleled opportunities for developing the three-dimensional study of the atmosphere.

* * * * *

Although there never were observation enough, yet there is always a danger of the meteorologist being swamped by the observations and records which pour in upon him; the danger is an increasing one as also is the tendency to regard observations as things of the moment to be thrown away or filed forever, immediately the forecaster has done with them. If the new service is successful in dealing with this problem its contribution to our knowledge of climate in and above the British Isles will be a more enduring monument than the apparently ephemeral achievement of an accurate forecast.

Finally, British meteorology is inseparable from the ocean; the pressing need for economizing our stores of accumulated energy make it desirable that the meteorology of the ocean should be put on a footing from which it can announce the energy practically available in the winds, the rate at which it can be supplied on any route, and the routes on which the maximum per mile can be attained. Warnings of gales, ice and fog, do not represent the only way in which the meteorology of the sea can contribute to the national welfare; but the effective use of the existing and increasing statistics of marine meteorology depends on a close liaison between the meteorologist, the shipping company, and the sailor. With a "meteorologist in every port" this ought now to be practicable.

BRITISH METEOROLOGICAL OFFICE STAFF.

Changes in the meteorological office staff have recently been made, and the following appointments have been announced: Mr. R. G. K. Lempfert becomes assistant director, and takes general oversight of observations and stations contributing observations to the office. Mr. Lempfert entered the meteorological office in 1902, and has been superintendent of the Forecast Division since 1910. Lieut. Col. E. Gold becomes assistant director, in charge of forecasting. Col. Gold graduated as third wrangler in 1902, and was elected fellow of St. John's College, Cambridge, in 1906; he was Schuster reader in dynamical meteorology from 1907 to 1910, and he then became superintendent of statistics at the meteorological office. On the formation of the meteorological section of the royal engineers in 1915 he was appointed to the command of the overseas contingent at general headquarters, France. Capt. D. Brunt is made superintendent of the work for army services. Capt. Brunt was in the meteorological section of the royal engineers during the war, ann acted under Col. Gold. Mr. Carle Salter becomes superintendent on the staff of the meteorological office for the British rainfall organization. Mr. Salter has recently been assistant director of the British rainfall organization, which has now come under the control of the meteorological office.—*Nature (London), Oct. 16, 1919.*

THE METEOROLOGICAL RESOURCES OF THE EMPIRE.

[Abstract, presidential address Royal Meteorological Society, Jan. 16, 1918, by Maj. [now Col.] H. G. Lyons.[1]]

When we examine the meteorological organizations of the Empire, we may well be astonished at their extent and development, but as we look further into the matter we shall see that we are still far from utilizing them to the best advantage.

In all countries where there is a meteorological service the network of climatological stations is controlled by one or more first-order stations, or meteorological observatories, at which continuous records or hourly readings of pressure, temperature, wind, sunshine, rain, etc., are taken, but none as yet exists in the great colonial regions of East Africa, West Africa, or in the West Indian Islands, though there are 18 institutions of this class in other parts of the Empire.

The work of the meteorologist does not end with recording pressure, or the temperature, or the monthly amount of rainfall, but meteorological observations, after being taken, must be worked up into the various forms in which they will be most useful for shipping, agriculture, water supply, engineering, sanitation, and health, and now, also, aerial transport. The same form will not suffice for all, and meteorology itself has its own especial needs, but the important thing is that this information, however accurate and detailed it may be, will not be available in exactly the forms that answer to different requirements unless there is a sufficient staff of trained meteorologists to handle it and to supervise its preparation.

Nor is the study of a single region sufficient in itself. India, in preparing the monsoon forecast, draws upon data from Egypt, St. Helena, Brazil, etc. Egypt, in forming each year an estimate of the coming Nile flood, utilizes information from India, Uganda, the South Atlantic, and so on. The East Indian Islands need warnings of their hurricanes from the more eastward islands of their archipelago, and must utilize all that Asia and Africa can tell them about the development and movement of tropical storms before their precautions can be considered to have exhausted all the means available. All lands which lie near the subtropical zones of scanty rainfall are vitally interested in the problems of forecasting the probable sufficiency or failure of their rainy season. The droughts of the pastoral regions of Australia and South Africa are well known, and the same occur in the Sudan, though from its retarded development less has been heard of them up to the present time, but in the future, as the population increases and becomes more settled, the same considerations will demand attention. Similarly, the tem-

[1] It is announced by the Times that a scheme for the amalgamation of the existing Government meteorological services has been approved, and the details are being arranged. Under the stress of war conditions the meteorological office was supplemented by the addition of three specially organized services, respectively in charge of the Admiralty, the army, and the air ministry, and the coming of peace thus found four more or less overlapping departments. The present scheme brings them together under the directorship of Sir Napier Shaw, who has acted for some time past in the capacity of meteorological advisor to the Government. The new amalgamated service will meet the, requirements of the army, navy, royal air force, of civil aviation, fisheries, engineering, and of all others who require meteorological information. It will * * * bring together information from all parts of the world."—*Symons's Meteorological Mag. Aug., 1919, p. 80.*

[1] Extracts from abstract in Nature (London), Jan. 24, 1918, vol. 100, pp. 416-417.

147217—19——4

peratures in the temperate zones find some of their most urgent problems in the adequacy or inadequacy of the summer heat for the ripening of cereal crops.

THE SUPPLY OF METEOROLOGICAL INFORMATION.

By Lieut. Col. H. G. LYONS.

[Abstracted from Aeronautics, Apr. 17, 1919, pp. 412-415.]

While aviation has come to be looked upon as the most important recipient of meteorological information, the fact remains that it is only one of many branches of human activity closely dependent on weather. Observations made for a certain specialized purpose, in the hands of the trained meteorologist, may often be used to further our knowledge of a branch of the science quite different from that for which it was originally intended. So it was with war meteorology—our observations of pilot balloons, of shell-bursts, etc., made for the immediate use of the army may now be employed to contribute to our knowledge of the processes at work in the atmosphere.

With stations so widely distributed as are those of the British Empire, it is absolutely essential that the closest cooperation be maintained. Not only should the methods of observation employed at each station and the instruments used for measurements be absolutely uniform, but as much information as possible should be acquired concerning the local characteristics of each individual station. Hand in hand with the idea of close cooperation among stations goes that of rapid transmission of information and the careful filing and indexing of it. Without the former it will fail in its immediate purpose; and without the latter it will lead to duplication of work, as well as other hinderances to the most efficient consideration of information.—*C. L. M.*

BRITISH EMPIRE METEOROLOGICAL CONFERENCE.

[Abstracted from Aeronautics, New York, Oct. 9, 1919, p. 344.]

The first conference of representative meteorologists from the Dominions held in London the last week in September under the presidency of Sir Napier Shaw included representatives from all the Dominions except Newfoundland, from Ceylon, India, and Egypt.

Col. L. F. Blandy read a paper on arrangements for transmission of meteorological information by wireless. He outlined a scheme covering the whole of Europe, the Mediterranean, and north Africa. The afternoon discussion was directed to the transmission of observations by wireless from ships at sea.

A. D. Spiers opened a discussion on the aerial routes Cairo-Karachi and Cairo to the Cape. The subject was considered from a meteorological standpoint. Subsequently Sir R. F. Stupart (Canada) raised the question of instruments and equipment for upper-air observations by means of pilot balloons. A decision was also reached on the best form of report for aviation purposes. The afternoon was devoted to the selection of stations for the general study of climatology of the globe.

AEROLOGICAL OBSERVATIONS IN POLAR REGIONS.

The Norwegian Meteorological Institute has suggested, in connection with the polar expedition of Roald Amundsen, that various Governments whose territories extend into polar regions, cooperate during the years 1920 to 1922 in the making of certain observations. These observations should comprise, in addition to regular surface meteorological information, pilot-balloon ascents, cloud observations, kites and captive balloon flights, observations of terrestrial magnetism, and photographic observations of aurorae. The stations should be as numerous as possible, and, whenever possible, should be connected by telephone or have radio apparatus, in order that observations of such phenomena as aurorae might be made simultaneously.

THE COMPUTER'S HANDBOOK.

By CAPTAIN E. H. CHAPMAN, R. E.

(Abstract.)

SECTION V. Computations related to the theory of probabilities. 3. A collection of correlation coefficients from Meteorological Papers and a note on the partial correlation coefficient.[1]

In 1915 there appeared subsections 1 and 2 of section V. Subsection 1 dealt with "Errors of observations and variations due to accidental causes with an application to errors of means and normals," by R. Corless, M. A.; and subsection 2, with "The practical application of statistical methods to meteorology," by W. H. Dines, F. R. S. The present subsection is a logical and very valuable continuation of the first two. An introduction by Sir Napier Shaw briefly reviews the history of correlation as applied to meteorology, and states that in order to avoid recomputing the same data all correlation coefficients available that are based on a sufficient number of observations are here brought together. Capt. Chapman has adopted 25 as the normal minimum of the number of pairs of figures to be correlated, although in a few instances, a smaller number has been accepted. In all cases the number of observations is given in the tables. It is pointed out that a preliminary investigation is necessary to determine whether or not the relationship approximates a straight line before the correlation method can be accepted as a proper measure of that relationship. The coefficients are arranged according to subject in the following groups:

1. Upper air.
2. Seasonal correlations.
3. Atmospheric pressure.
4. Temperature.
5. Rainfall.
6. Sunspots.
7. Weather and crops.

Section 7 contains, among others, the results of studies in the United States by T. A. Blair, J. Warren Smith and J. F. Voorhees. A subject index makes it possible quickly to find values in which the reader is most interested and a note at the end of the work describes an alternative method of obtaining partial correlation coefficients to that already given by Dines in subsection 2.—*W. R. G.*

[1] Published by the authority of the Meteorological Committee. London, 1919.

CONTINENTALITY AND TEMPERATURE.

By C. E. P. BROOKS.

(Abstracted from Quart. Jour. Royal Meteorological Soc., April, 1917, pp. 159-174; and October, 1918, pp. 253-270.)

The problem of determining the power and influence of the geographical changes of the earth on temperature has been approached by the mathematical method of partial correlation. The region selected for this investigation lies between the latitudes 40° and 60° north, and the western coast of Europe east to longitude 90° east. The stations, 56 in number, were given their proper coordinates of height, continentality, and radiation received. Continentality refers to the percentages of land and water area inside concentric circles centered at the station. These measures are termed C_5, C_{10}, C_{20}, respectively, the subscripts giving the radius of the circles in degrees. By finally determining the partial correlation coefficients between the variables, continentality, height, and radiation, on the one hand, and temperature on the other, the following conclusions were reached:

First. *Effect of height.*—Two stations in same latitude and having the same continentality coefficients, but differing in altitude by 100 meters, should differ in their mean temperature by 0.61°C. in January and 0.45°C. in July. These figures are quite within the limits of the observed values.

Second. *Effect of radiation.*—Two stations at the same altitude and having equal continentality coefficients but differing in latitude by 20° should differ by 19.2° C. in January and 7.1° C. in July, the more southerly being the warmer in each case.

Third. *Effect of continentality.*—Expressing the continentality coefficient in terms of degrees (C.) per square kilometer, we find:

	C_{10-20} (°C$\times10^{-9}$)	C_{5-10} (°C.$\times10^{-9}$)	C_{0-5} (°C.$\times10^{-9}$)
January	−33	−164	−21
July	+40	−20	+111

Fourth. It appears that with continentality 0, i. e., a station entirely surrounded by sea for at least 20° the basal temperature (effect of sun's heat not included) for January is 284.9° A., and for July 227° A. Where continentality is 50, basal temperature is 269.1° A. for January and 232.9° A. for July. Where continentality is 100, i. e., no water within 20° radius, the temperatures for January and July are, respectively, 253.3° A. and 238.7°A.

These figures signify that, apart from radiation from the sun and sky, the difference, heat received − heat given away, is very much greater (algebraically) in winter than in summer. This heat transference takes place partly as actual radiation to the sky, and partly by the agency of the wind and convectional currents.

An attempt to discuss the temperatures changes in different geological ages was made, and the period chosen was the Litorna time "when the Baltic was larger and more salt than now, and when the Scandinavian countries had a warmer and more temperate climate, as shown by the distribution of animals and plants at that peroid." Upon reconstructing a map to conform with the probable distribution of land in that period, it was found that certain of the continentality factors balanced each other, with the result that there was little or no change of temperature as a result. The conclusion was, not that the temperature distribution of that age did not differ from the present, but that the equations employed in obtaining present values were good only when applied to the present land and sea distribution of Europe. Hence, new equations were formed which resulted in showing that the January temperatures over the northern Baltic exceeded the present by 3°; south of that point the temperatures decreased until northern Germany was slightly colder than at present. This is shown to agree with the opinions of the most eminent authorities, and emphasizes the fact that changes of continentality are entirely sufficient, without any astronomical considerations, to account for changes of climate in long periods.

In summarizing the results of the investigation, I may confidently say that the method of partial correlation in connection with land and sea distribution is a powerful tool in the hands of climatologists and geologists, but it is a tool of a very technical nature, and expertness in its use can only be gained by practice.

The second paper is a more elaborate treatment of the effect of continentality on temperature, and takes up the effect of latitude. This point was neglected in the first paper because of the small region of the earth's surface employed in the discussion; but here the whole world is considered, and, obviously, the effect of latitude is an important factor. In this investigation, the average mean temperature in January and July at each point of intersection of two 10° coordinates were obtained, and then these values were compared with the percentage of land within a 10° circle around the point of intersection. Land to the east and west of each point, as well as ice, was expressed in percentage, and each point was treated by the method of partial correlation for effect of land to the west, supposing land to the east, and ice, constant; then, the effect of land to the east, with land to the west, and ice, constant, and the effect of the ice supposing land to the east and west constant. The temperature was obtained by this formula: Temperature = basal temperature + ice coefficient × percentage of ice + land west coefficient × percentage of land west + land east coefficient × percentage of land east.

The following interpretation of the results from a geographical standpoint is obtained:

1. In winter the effect of land to the west is always to lower temperature. This holds in every case except at 10° south and 20° south.
2. In winter, the effect of land to the east is almost negligible. The only important exception to this rule is 70° north, which may be considered as coming within a belt of polar east winds.
3. In summer, the general effect of land whether to east or west is to raise temperature, but the effect is nowhere anything like so marked as the opposite effect in winter.

In discussing the influence of the distribution of insolation it is interesting to note that while the water hemisphere reaches its maximum calculated temperature in latitude 10° south, the land hemisphere has its maximum at 30° south. The maximum of heat received in January occurs at about 33° south. The thermal equator is thus much less mobile over the ocean than over the land.

The glacial periods are discussed, leading to the following generalization: "Over the earth as a whole the glacial period was due not alone to fall of temperature or to increased snowfall, but to both, the former being predominant in high latitudes and decreasing toward the Tropics where it vanished, and the latter increasing from a small but effective part near the poles until in the Tropics it was the sole cause." The theory of climatic evolution is outlined on the basis of rise and fall of the earth's crust, under the weight of the ice sheet. The

rise of the earth causing a lowering of temperature with the consequent formation of glaciers, the weight of the ice sheet in turn causing the crust to sink back, raising the temperature and melting the ice. This is traced through four periods, the maximum rise of land in each period being less than in the preceding. Thus it is demonstrated that the "climates of the world are the result of geographical conditions of the world," and "that within certain limits climatic and geographic conditions react one on another to produce continuous though very slow changes in both."—*C. L. M.*

PERIODICITY OF WINTER TEMPERATURES IN WESTERN EUROPE.[1]

By C. EASTON.

[Reprinted from Science Abstracts, Sect. A, Sept. 30, 1918, §913.]

All available data are collected and carefully sifted, reports of exceptionally mild winters being used in addition to those of severe ones. Each abnormal winter is given a coefficient of temperature ranging between +5 and −5, the remaining winters being marked zero. The series covers 1,157 years. The data are investigated with a view to determining periodicities. An 89-year period is traced and it is further found that in the past 65 years, for which reliable thermometric observations are available, the temperature sequence of this 89-year period can be clearly followed, thus affording confirmation of its reality. The chief features of the fluctuation are that in the first quarter of the 89 years cold winters prevail and in the last quarter warm ones. A sine wave of 44½ years seems to be an important part of the 89-year fluctuation. It is considered that the results are sufficiently definite to be of some assistance in long-range forecasting. No evidence is found of a gradually increasing or decreasing frequency of severe winters in historical times.[2]—*J. S. Di[nes.]*

[1] Physikalische Zeitschrift, June 1, 1918, 19 : 234-237.

[2] See also review in Geogr. Rev., 1918, 4 : 398.

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RECENT ADDITIONS TO THE WEATHER BUREAU LIBRARY.

C. FITZHUGH TALMAN, Professor in Charge of Library.

The following have been selected from among the titles of books recently received as representing those most likely to be useful to Weather Bureau officials in their meteorological work and studies:

Bavaria. Meteorologische Centralstation.

Deutsches meteorologisches Jahrbuch für 1914-15. Jahrgang 36-37. München. 1916-19. 2v. charts (part. fold.) tables. 33 cm.

Cienfuegos. Colegio "Nstra. Snra. de Montserrat." Observatorio.

Anales. No. 8. Observaciones meteorológicas de 1918. Habana. 1919. tables. 32½ cm.

Colombo. Observatory.

Report for the year 1918. Colombo. 1919. 2 p. l., J1-J20 p. charts (part. fold.) tables. 33½ cm. (Reprinted from the Ceylon blue book for 1918.)

Dorno, C[arl Wilhelm Max].

Welchen Nutzen bringen die Polarisationsbeobachtungen der atmosphärischen Optik, Meteorologie, Geophysik und Astronomie? charts (part. fold.) 23½ cm. (In Mitteilungen der Vereinigung von Freunden der Astronomie und kosmischen Physik, Berlin. 29 Jahrg. Heft 6/7. Sept. 1919. p. 71-86.)

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Geology and ground waters of the western part of San Diego county, California, by A. J. Ellis and C. H. Lee . . . Washington. 1919. 321 p. plates. maps (part. fold.) charts (part. fold.) tables. diagrs. (part. fold.) 23½ cm. At head of title: Department of the interior. U. S. Geological survey. Water-supply paper 446. "Publications consulted," p. 288-290. [Includes extensive data of precipitation and evaporation, largely from non-Weather Bureau stations.]

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Movimiento de las nubes altas y medias en el zenit de Barcelona. Con la colaboración de D. G. Campo Cunchillos. Barcelona. 1919. 11 p. charts. tables. 29½ cm. At head of title: Memorias de la Real academia de ciencias y artes de Barcelona. Tercera época. Vol. 15. Núm. 8.

Great Britain. Meteorological office.

Codex of resolutions adopted at International meteorological meetings. Supplement summarising the resolutions adopted by the International meteorological committee meetings held in Berlin, 1910, and Rome, 1913. London. 1919. 12 l., 25 cm. M. O. No. 200.

Professional notes no. 4-7. London. 1919. 4v. charts. tables. 24½ cm. M. O. 232d-g. Contents: (4) Upper air temperatures at Martlesham Heath, Feb. 1917 to Jan. 1918, by W. F. Stacey. (5) On the use of the normal curve of errors in classifying observations in meteorology, by E. H. Chapman. (6) The variation of wind velocity with height, by E. H Chapman. (7) The climate of north-west Russia. [See abstracts, MONTHLY WEATHER REVIEW, Aug., 1919, **47**: 572.]

Great Britain. Meteorological office. Advisory committee on atmospheric pollution.

Report on observations in the year 1917-18. Forming the 4th report of the committee for the investigation of atmospheric pollution. London. [1919] 23 p illus. tables. charts. 29 cm.

Grover, Nathan C[lifford].

Surface water supply of Hawaii, July 1, 1917 to June 30, 1918. . . . Washington. 1919. 172 p. tables. 23 cm. At head of title: Department of the interior. U. S. Geological survey. Water-supply paper 485. [Rainfall, p. 163-167.]

Guam. Agricultural experiment station.

Report, 1918. Washington. 1919. 61 p. plates. tables. 23½ cm. [Meteorological observations, July, 1917-June, 1918, incl. Observations were taken in Guam during the fiscal years 1912-1914 and recommenced on July 1, 1917.]

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Observations météorologiques, 1918. Guernsey. 1919. 20. p. tables. 28 cm.

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On the propagation of sound in the free atmosphere and the acoustic efficiency of fog-signal machinery; an account of experiments carried out at Father Point, Quebec, September, 1913. London. 1919. cover-title. plate. illus. charts. tables. 30½ cm. At head of title: Philosophical transactions of the Royal society of London. Series A, Vol. 218. p. 211–293.

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Sulla frequenza degli aloni. Nota 1-5. tables. 30½ cm. (Estratto dagli Atti della Pontifica accademia romana dei Nuovi Lincei. Sessione 1ª del 17 diciembre 1916-sessione 5ª del 13 aprile, 1919.)

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Weather forecasting in New Zealand. Wellington, N. Z. 1919. cover-title. charts. 25 cm. At head of title: From the New Zealand journal of science and technology. Vol. 2, no. 2, p. 87–94, and no. 3, p. 165–179, 1919.

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Isförhållandena i Helsingfors hamn. Helsingfors. 1913. 10 p. 5 tables. 22½ cm.

Om sommarregnen och deras hydrologiska konsekvenser. Studier byggda på och föranledda av iakttagelser inom tvenne delområden av vanda vattensystem åren 1912–1914. Helsingfors. 1917. 2 p. l., 220 p. front. (fold. map) charts. tables. 24½ cm.

Om sommarregnens dagliga period i NW-och Mellaneuropa. Helsingfors. 1918. 11 p. charts. 24 cm. At head of title: Öfversigt af Finska vetenskapssocietetens förhandlingar. Bd. 60. 1917–1918. Afd. A no. 5. Abstract in German, p. 10–11.

Största dagsummor av nederbörden i Finland. Helsingfors. 1915. 12 p., l. charts. tables. 25 cm. Abstract in German on final leaf.

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Art motives in snow crystals. illus. 25 cm. (In Natural history Journal of the American museum of natural history, N. Y. Vol. 19, April-May, 1919, nos. 4-5, p. 436–440.)

RECENT PAPERS BEARING ON METEOROLOGY AND SEISMOLOGY.

C. F. TALMAN, Professor in Charge of Library.

The following titles have been selected from the contents of the periodicals and serials recently received in the Library of the Weather Bureau. The titles selected are of papers and other communications bearing on meteorology and cognate branches of science. This is not a complete index of all the journals from which it has been compiled. It shows only the articles that appear to the compiler likely to be of particular interest in connection with the work of the Weather Bureau.

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Meggers, W. F., & Peters, C. G. Measurements on the index of refraction of air for wave-lengths from 2218A to 9000A. p. 56-71.

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Jones, Loyd A. The low visibility phase of protective coloration. p. 363-387; 507-533. (Sept., Oct.). [Discusses weather factors and describes a visibility-meter].
Humphreys, W[illiam] J[ackson]. Optics of the air. p. 433-488. (Oct.)
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Bouant, Émile. Les feux follets. p. 705-707.

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Bustamante, Octavio. Las lluvias en los años de 1917 y 1918. p. 17-20.

Egatea. Porto Alegre. v. 5. Agosto, 1919.
Coussirat de Araujo, L. Invernos frios e invernos quentes. p. 78-80.

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Crestani, Giuseppe. Le cappe. Nota 2. p. 1-9.
Gicres. La legge di Buys-Ballot e il vento in Italia. p. 9-10.
Toller, Francesco. L'aeronavigazione e le correnti aeree. p. 17-32.
Negro, Carlo. Di alcuni aloni osservati in Torino nel 1917. p. 10-16.

SPECIAL OBSERVATIONS.

SOLAR AND SKY RADIATION MEASUREMENTS DURING SEPTEMBER, 1919.

By HERBERT H. KIMBALL, Professor of Meteorology, in charge.

[Dated: Solar Radiation Investigations Section, Washington, Oct. 30, 1919.]

For a description of instrumental exposures and an account of the methods of obtaining and reducing the measurements, the reader is referred to the REVIEW for January, 1919, **47**:4.

The monthly means and departures from normal in Table 1 show that radiation measurements averaged close to September normal values at Washington and Santa Fe, slightly above normal at Madison, and slightly below at Lincoln.

Table 3 shows only slight departures from the normal amount of radiation for the month at the three stations having continuously recording pyrheliometers. At Washington, the Leeds and Northrup recorder heretofore used was replaced by a Callendar recorder on September 27, necessitating a redetermination of the reduction factor for the pyrheliometer.

The skylight polarization measurements made at Washington on 8 days give a mean of 59 per cent, with a maximum of 67 per cent on the 25th. At Madison, measurements made on 12 days give a mean of 67 per cent, with a maximum of 73 per cent on the 12th. These are average values for September.

TABLE 1.—*Solar radiation intensities during September, 1919.*

[Gram-calories per minute per square centimeter of normal surface.]

Washington, D. C.

Date.	Sun's zenith distance.									
	0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass.									
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Sept. 3	1.19	1.06	0.94	0.82	0.68	0.61	0.56	0.50	0.44	0.38
4	......	1.02	0.92	0.83	0.74	0.67	0.61	......	......	......
8	......	0.85	0.73	0.64	......	......	......	......	......	......
12	1.37	1.26	1.18	1.04	0.93	0.89	0.83	0.77	0.71	......
13	......	1.28	1.17	1.09	1.05	0.98	0.92	0.85	......	......
24	......	1.24	1.09	0.99	0.93	0.87	0.81	......	......	......
25	1.43	1.30	1.18	1.06	0.98	0.91	0.84	......	......	......
26	......	1.11	0.93	0.77	0.65	0.59	0.54	......	......	......
27	......	1.32	1.15	1.02	0.90	0.81	0.76	......	......	......
Monthly means	**1.33**	**1.16**	**1.03**	**0.92**	**0.86**	**0.79**	**0.73**	**0.71**	**(0.58)**	**(0.38)**
Departure from 11-year normal	**+0.01**	**−0.04**	**−0.04**	**−0.06**	**−0.02**	**±0.00**	**+0.01**	**+0.05**	**−0.06**	**−0.22**
P. M.										
Sept. 16	......	0.96	0.84	......	......	......	0.67	......	0.43	0.38
18	......	1.12	0.53	......	......	......	......	......	......	......
24	......	1.30	1.06	......	......	......	......	......	......	......
25	......	1.30	1.18	1.07	0.98	0.91	0.85	0.80	0.73	0.66
26	......	1.29	1.17	1.07	0.99	0.91	0.71	0.63	......	......
27	......	1.34	1.11	1.01	0.91	0.83	0.77	0.71	0.65	......
Monthly means	......	**1.22**	**0.98**	**1.05**	**0.96**	**0.88**	**0.75**	**0.71**	**0.60**	**(0.52)**
Departure from 11-year normal	......	**+0.02**	**−0.03**	**+0.09**	**+0.08**	**+0.08**	**+0.01**	**−0.01**	**−0.07**	**−0.07**

Madison, Wis.

Date.	0.0° (1.0)	48.3° (1.5)	60.0° (2.0)	66.5° (2.5)	70.7° (3.0)	73.6° (3.5)	75.7° (4.0)	77.4° (4.5)	78.7° (5.0)	79.8° (5.5)
A. M.										
Sept. 1	......	1.27	1.12	1.02	......	0.90	......	0.81	......	......
4	......	1.29	......	......	......	......	......	......	......	......
8	......	1.17	......	......	......	......	......	......	......	......
11	[1] 1.48	1.35	1.22	1.11	1.03	0.97	0.92	0.86	0.81	0.78
12	......	1.40	......	1.21	1.17	1.13	1.08	1.04	0.99	0.95
15	[1] 1.46	1.33	......	1.13	......	......	......	......	......	......
16	[1] 1.45	1.33	1.24	1.15	1.07	0.98	0.92	......	......	0.82
22	[1] 1.51	1.41	1.32	1.24	1.16	1.09	1.02	0.95	0.94	0.87
23	......	1.42	1.29	1.21	1.15	1.08	1.03	0.96	0.90	0.88
24	......	1.37	1.29	1.17	1.08	1.02	0.97	......	......	0.84
27	......	1.29	1.22	......	......	......	......	......	......	......
Monthly means	......	**1.33**	**1.24**	**1.16**	**1.11**	**1.02**	**0.99**	**0.92**	**0.91**	**0.86**
Departure from 10-year normal	......	**+0.06**	**+0.07**	**+0.09**	**+0.10**	**+0.07**	**+0.10**	**+0.03**	**+0.01**	......
P. M.										
Sept. 4	......	1.26	1.14	1.02	0.92	0.84	......	......	......	......
11	......	1.38	1.25	1.14	......	......	......	......	......	......
12	......	1.32	1.27	1.12	1.06	1.01	......	......	......	......
15	......	1.32	1.19	1.14	1.07	0.98	......	......	......	......
16	......	1.33	1.18	1.05	0.98	0.91	......	......	......	......
20	......	1.09	1.04	0.98	0.89	0.84	0.72	......	......	......
22	......	1.41	......	......	......	......	......	......	......	......
23	......	......	1.24	......	......	......	......	......	......	......
26	......	......	1.09	......	......	......	......	......	......	......
27	......	1.28	......	......	......	......	......	......	......	......
Monthly means	......	**1.30**	**1.18**	**1.08**	**0.98**	**0.92**	**(0.72)**	......	......	......
Departure from 10-year normal	......	**+0.04**	**+0.03**	**+0.03**	**−0.02**	**+0.07**	**−0.11**	......	......	......

[1] Extrapolated and corrected for mean solar distance.

TABLE 2.—*Solar radiation intensities during September, 1919*—Contd.

Lincoln, Nebr.

Date.	Sun's zenith distance.									
	0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass.									
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Sept. 1	[1] 1.24	1.14	1.07	1.01	0.92	0.87	0.81	......	......	......
6	[1] 1.26	1.11	0.97	0.87	0.78	0.71	0.63	0.56	0.51	......
9	[1] 1.29	1.17	1.04	0.95	0.86	0.80	0.76	......	......	......
11	[1] 1.40	1.26	1.13	1.03	0.95	0.89	0.82	......	......	......
23	......	1.34	1.25	1.12	1.06	0.95	0.88	......	......	......
25	[1] 1.43	1.31	1.21	1.13	1.03	0.95	......	......	......	......
26	......	1.36	1.26	1.17	1.07	0.99	......	......	......	......
Monthly means	......	**1.24**	**1.13**	**1.04**	**0.95**	**0.88**	**0.78**	**(0.56)**	**(0.51)**	......
Departure from 6-year normal	......	**−0.04**	**−0.04**	**−0.03**	**−0.03**	**−0.02**	**−0.04**	**−0.19**	**−0.21**	......
P. M.										
Sept. 5	[1] 1.43	......	1.02	0.93	0.83	0.74	0.65	0.58	0.53	0.48
9	......	......	......	0.86	......	......	......	......	......	......
11	......	1.25	1.11	1.01	0.94	0.88	0.84	0.80	0.75	0.72
23	......	......	1.24	1.12	1.02	0.91	0.79	......	......	......
25	......	1.30	1.19	1.09	1.00	0.92	0.84	0.77	0.70	0.63
26	......	1.36	1.23	1.11	1.02	0.94	......	......	......	......
Monthly means	......	**1.30**	**1.16**	**1.02**	**0.96**	**0.88**	**0.78**	**0.72**	**0.66**	**0.61**
Departure from 6-year normal	......	**+0.02**	**+0.01**	**−0.03**	**±0.00**	**−0.02**	**−0.05**	**−0.04**	**−0.07**	**−0.07**

Santa Fe, N. Mex.

Date.	0.0° (1.0)	48.3° (1.5)	60.0° (2.0)	66.5° (2.5)	70.7° (3.0)	73.6° (3.5)	75.7° (4.0)	77.4° (4.5)	78.7° (5.0)	79.8° (5.5)
A. M.										
Sept. 5	......	1.32	......	......	......	......	......	......	......	......
10	......	1.47	1.36	......	......	......	......	......	......	......
11	......	......	......	1.24	1.17	1.09	1.02	0.95	0.89	......
17	......	......	1.32	......	......	......	......	......	......	......
18	......	......	......	......	0.97	......	......	0.81	......	......
25	[1] 1.53	1.45	......	......	......	1.18	1.12	1.06	1.01	0.96
Monthly means	......	**1.41**	**(1.34)**	**(1.24)**	**(1.07)**	**(1.14)**	**(1.07)**	**0.94**	**(0.95)**	**(0.96)**
Departure from 7-year normal	......	**+0.01**	**+0.03**	**±0.00**	**−0.08**	**+0.03**	**−0.01**	**−0.06**	**−0.01**	**+0.04**
P. M.										
Sept. 25	[1] 1.53	1.44	1.36	1.29	1.22	1.15	1.09	1.03	......	......
27	......	......	......	1.36	......	......	......	......	......	......
28	......	......	......	1.34	1.25	......	1.19	1.14	1.09	......
Monthly means	......	**(1.44)**	**(1.36)**	**1.33**	**(1.24)**	**(1.15)**	**(1.14)**	**(1.08)**	**(1.09)**	......
Departure from 7-year normal	......	**−0.02**	**−0.01**	**+0.02**	**+0.03**	**+0.01**	**+0.04**	**+0.05**	**+0.13**	......

[1] Extrapolated and corrected for mean solar distance.

TABLE 2.—*Vapor pressures at pyrheliometric stations on days when solar radiation intensities were measured.*

Washington, D.C.			Madison, Wis.			Lincoln, Nebr.			Santa Fe, N. Mex.		
Date.	8 a.m.	8 p.m.	Date.	8 a.m.	8 p.m.	Date.	8 a.m.	8 p.m.	Date.	8 a.m.	8 p.m.
1919.	*mm.*	*mm.*	1919.	*mm.*	*mm.*	1919.	*mm.*	*mm.*	1919.	*mm.*	*mm.*
Sept. 3	8.81	12.68	Sept. 1	9.83	6.76	Sept. 1	8.48	8.81	Sept. 5	7.57	5.56
4	10.21	14.60	4	10.21	8.81	5	10.59	9.83	10	9.14	7.57
8	16.79	16.79	8	14.60	15.11	6	12.24	11.81	11	9.14	10.59
12	8.48	7.29	11	10.97	7.87	9	16.20	17.37	17	9.47	7.29
13	8.48	10.21	12	7.87	7.57	11	12.68	8.48	18	8.81	8.48
16	13.13	10.21	15	10.97	10.97	23	6.50	8.48	25	5.36	4.95
18	7.87	8.81	16	9.47	9.14	25	6.76	6.76	27	8.48	7.29
24	9.83	11.38	20	14.10	16.79	26	9.14	10.21	28	7.29	5.79
25	9.83	10.21	22	7.87	7.29						
26	7.87	7.87	23	7.04	7.57						
27	7.04	9.47	24	7.29	7.29						
			26	5.36	6.50						
			27	7.87	10.59						

TABLE 3.—*Daily totals and departures of solar and sky radiation during Sept., 1919.*

(Gram-calories per square centimeter of horizontal surface.)

Day of month.	Daily totals.			Departures from normal.			Excess or deficiency since first of month.		
	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.
	cal.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
1	413	532	587	10	134	137	10	134	137
2	322	284	314	−80	−111	−133	−70	23	4
3	493	134	377	93	−257	−68	23	−234	−64
4	413	486	502	15	98	59	38	−136	−5
5	399	458	558	3	73	117	41	−63	112
6	462	480	530	68	99	92	109	36	204
7	419	446	562	27	70	128	136	106	332
8	414	430	553	24	58	122	160	164	454
9	269	169	496	−120	−198	68	40	−34	522
10	70	251	310	−317	−112	−114	−277	−146	408
11	340	523	553	−45	165	132	−322	19	540
12	478	499	519	95	145	101	−227	164	641
13	505	417	291	123	67	−122	−104	231	519
14	454	192	486	74	−153	75	−30	78	594
15	340	466	376	−38	125	−32	−68	203	562
16	404	492	270	28	155	−135	−40	358	427
17	373	198	152	0	−136	−251	−40	222	176
18	450	92	48	79	−238	−352	39	−16	−176
19	212	235	403	−156	−92	5	−117	−108	−171
20	331	253	501	−35	−70	105	−152	−178	−66
Decade departure	......	......	......	......	......	......	**125**	**−32**	**−474**
21	343	70	202	−20	−250	−191	−172	−428	−257
22	120	466	521	−241	150	130	−413	−278	−127
23	37	466	524	−321	153	135	−734	−125	8
24	457	462	504	101	153	118	−633	28	126
25	454	466	526	101	160	142	−532	188	268
26	455	346	540	105	43	159	−427	231	427
27	414	430	103	68	130	−274	−359	361	153
28	393	81	171	50	−215	−203	−309	146	−50
29	332	94	75	−7	−199	−295	−316	−53	−345
30	350	52	126	14	−238	−241	−302	−291	−586
31	......	......	......	......	......	......	......	......	......
Decade departure	......	......	......	......	......	......	**−150**	**−113**	**−520**
Excess or deficiency since first of year. gr.-cal.	......	......	......	......	......	......	**−4999**	**−3657**	**−2534**
Excess or deficiency since first of year. per cent.	......	......	......	......	......	......	−4.8	−3.5	−2.1

MEASUREMENTS OF THE SOLAR CONSTANT OF RADIATION AT CALAMA, CHILE.

By C. G. ABBOT.

[Dated: Astrophysical Observatory, Smithsonian Institution, Washington, Oct. 13, 1919.]

In continuation of preceding publications I give in the following table the results obtained at Calama, Chile, in August, 1919, for the solar constant of radiation. The reader is referred to this REVIEW for February, 1919, and July, 1919, for statements of the arrangements and meaning of the table.

During the present month the observations have been made very largely by the new method which was described in the REVIEW for the last-mentioned date, but part of them are also by the old method on which the new is fundamentally based. The reader will see that generally the agreement between the different determinations,

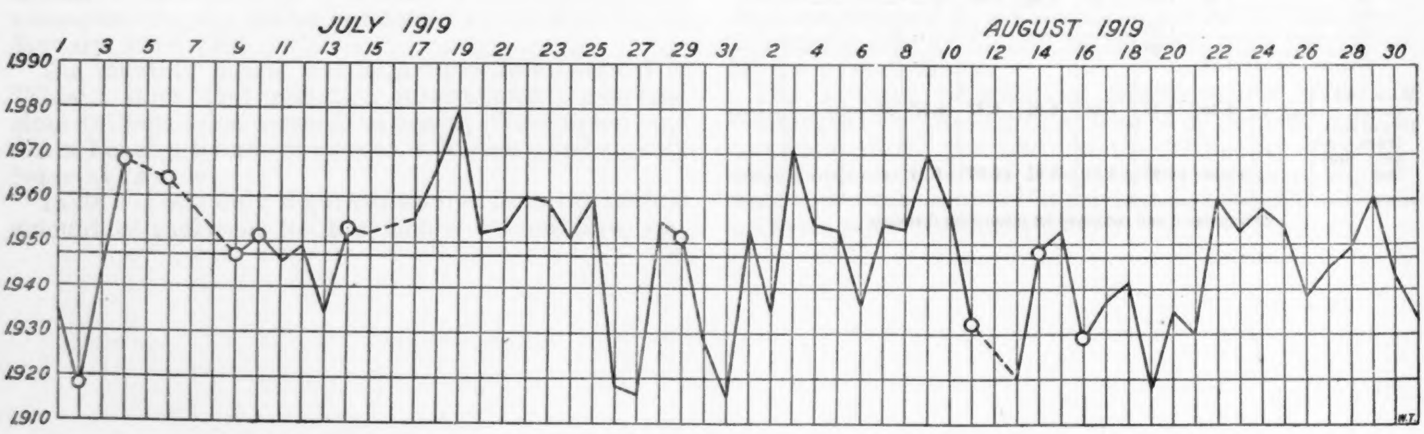


FIG. 1.—Solar constant values obtained at Calama, Chile. (Where circles are shown, but one set of observations is represented.)

whether by the old method, or by the new at air mass 2, air mass 3, or some other odd air mass, are in close agreement. Generally two, and sometimes three or four independent determinations are given for each day. Their usually close agreement seems to me to warrant much higher faith than formerly in the accuracy of the representative values for the individual dates.

In further support of the trustworthiness of the new method I give the following brief table taken from results which Messrs. Moore and Abbot have recently computed covering 53 days in which observations were made by both the old and the new methods.

Number of departures of specified magnitudes in calories.

	0-0.005	0.005-0.010	0.010-0.020	0.020-0.030	0.030-0.040	0.040-∞
No. (+)....	7	4	8	4	5	4
No. (−)....	5	2	6	4	2	3

From this table it appears that on 32 out of 53 days the deviations between the results by the two methods were less than 1 per cent, and that in 46 out of 53 days the deviations were less than 2 per cent. From notes which accompany the actual observations it is apparent that on most of the days when large deviations occur between the old and the new methods, the cause of these large deviations arose from the fact that the sky was either clearing or growing more hazy, so that the result by the old method was in error in the sense in which the deviations actually occurred. Thus, we may confidently believe, I think, that the results by the new method are trustworthy, and more particularly so where they are supported by observations at air mass 3 as well as at air mass 2. Not only so, but they are more trustworthy than results by the old method because the changes of the transparency of the atmosphere are eliminated. Although the present month of August was not particularly favorable, owing to a larger number of clouds than usual, yet the observers were able to secure good results on 30 days out of 31 owing to the availability of the new method.

As further evidence of the trustworthiness of the results obtained, the reader is invited to plot the weighted mean values as ordinates against the successive days as abscissae and note the comparative smoothness and step-by-step march of the curve from maximum to minimum and return.

Date.	Solar constant.	Method	Grade.	Transmission coefficient at 0.5 micron.	Humidity. $\rho/\rho sc.$	Humidity. V. P.	Humidity. Rel. hum.	Remarks.
1919. A. M.	*Cal.*					*Cm.*	%	
Aug. 1	1.951	E_0	E	0.872	0.618	0.09	13	
	1.952	M_3						
	1.956	M_2						
	1.953	W. M.						
2	1.928	M_3	S	.872	.506	.17	17	Cumuli low in east.
	1.938	M_2						
	1.935	W. M.						
3	1.980	M_3	S	.861	.425	.03	27	Cumuli low in east.
	1.966	M_2						
	1.971	W. M.						
1919. A. M.	*Cal.*					*Cm.*	%	
Aug. 4	1.954	M_3	S	0.867	0.502	0.23	23	
	1.949	M_2						
	1.954	W. M.						
5	1.936	E_0	VG−	.862	.522	.16	21	Some small cumuli in east and north, but disappearing.
	1.978	M_3						
	1.957	M_2						
	1.953	W. M.						
6	1.934	M_3	S	.857	.503	.11	13	Many thin cirro-cumuli in south.
	1.937	M_2						
	1.936	W. M.						
7	1.943	M_3	S	.867	.583	.13	17	
	1.959	M_2						
	1.954	W. M.						
8	1.967	E_0	E−	.860	.654	.13	22	
	1.949	M_3						
	1.949	M_2						
	1.953	W. M.						
9	1.981	M_3	S	.867	.604	.18	25	
	1.971	$M_{2.5}$						
	1.965	M_2						
	1.970	W. M.						
10	1.957	M_3	S+	.870	.590	.14	22	Some cirri in southeast.
	1.959	M_2						
	1.958	W. M.						
11	1.932	M_2	S	.807	.712	.10	9	Scattered cirri over much of sky.
13	1.937	E_0	G+	.836	.575	.11	17	
	1.911	M_2						
	1.920	W. M.						
14	1.948	M_2	U+	.850	.574	.31	27	Cirri in south and east and scattered cumuli in north.
15	1.964	M_3	S−	.868	.595	.15	16	Few cumuli in north.
	1.930	M_2						
	1.953	W. M.						
P. M. 16	1.929	M_2	U+	.854	.689	.16	10	Scattered cumuli in north and east in a. m. Cumuli in distant east and west in p. m.
A. M. 17	1.940	M_3	S	.855	.521	.21	18	Scattered cirri about sky, but none near sun.
	1.950	M_2						
	1.947	W. M.						
18	1.988	E_0	VG+	.864	.691	.08	12	Distant cirri in northeast and southwest.
	1.940	M_3						
	1.947	M_2						
	1.951	W. M.						
19	1.919	M_2	S	.862	.592	.11	11	Scattered cirri about sky.
	1.916	$M_{2.57}$						
	1.918	W. M.						
20	1.932	M_3	S	.867	.507	.19	19	Distant cirri in west.
	1.936	M_2						
	1.935	W. M.						
21	1.944	M_3	S−	.866	.480	.15	16	
	1.916	M_2						
	1.930	W. M.						
22	1.959	E_0	E	.862	.493	.18	19	
	1.972	M_3						
	1.956	M_2						
	1.960	W. M.						
23	1.952	M_3	S	.869	.592	.19	19	
	1.953	M_2						
	1.953	W. M.						
24	1.932	M_3	S−	.859	.618	.12	12	
	1.967	M_2						
	1.958	W. M.						
25	1.944	M_3	S−	.866	.638	.14	15	
	1.958	M_2						
	1.954	W. M.						
26	1.937	E_0	VG+	.864	.596	.15	22	
	1.923	M_3						
	1.947	M_2						
	1.938	W. M.						
27	1.938	M_3	S	.871	.626	.10	13	
	1.949	M_2						
	1.945	W. M.						
28	1.947	M_3	S	.873	.666	.10	14	
	1.950	M_2						
	1.949	W. M.						
29	1.961	E_0	VG+	.865	.690	.20	12	
	1.960	M_3						
	1.958	M_2						
	1.961	W. M.						
30	1.935	M_3	S−	.872	.724	.07	8	
	1.947	M_2						
	1.943	W. M.						
31	1.922	M_3	S−	.872	.723	.06	9	
	1.940	M_2						
	1.934	W. M.						

WEATHER OF THE MONTH.

WEATHER OF NORTH AMERICA AND ADJACENT OCEANS.

GENERAL CONDITIONS.

By A. J. HENRY, Meteorologist.

In September in the Northern Hemisphere the barometric gradients are the weakest of the year and the control of the surface winds is least pronounced. The area of maximum pressure still overlies the middle portion of the North Atlantic with a westward extension into the eastern half of the North American continent. The barometer level in this HIGH is below 30.20 inches. Mean pressure is lowest in the Arctic with centers of greatest depression in the vicinity of Iceland and over the Aleutians. The change in mean pressure from August to September leads to the reestablishment of the continental HIGHS and is preparatory to the setting in of the vigorous circulation of winter.

NORTH PACIFIC OCEAN.

F. G. TINGLEY, Meteorologist.

Additional ship reports, as well as press dispatches, give further evidence of unusual typhoon activity in Asiatic waters during the present season, the series of tropical storms which began near the end of July continuing beyond the middle of September.

The first of the September typhoons had its inception during the closing days of August and reached the Eastern Sea to the northward of Formosa during the night of the 31st. The U. S. Army transport *Sherman*, from Manila for Nagasaki, felt the full force of this storm near latitude 27° N., longitude 127° E., during the day and night of September 1. Mr. Paul R. Wright [1] gives the following account of the conditions at the height of the storm:

> At daylight I crawled out again and for some hours was privileged to behold one of the wildest and most sublime scenes that men have ever looked upon and lived to tell about. The storm was at its height. The wind was coming in gusts that reached 120 miles an hour. The air was simply filled with the white spume of the sea, just as the air is filled with snow in a great storm at home. To windward it was impossible to see more than 100 feet and to leeward not much farther. Yet through this white welter we could see something of the heights and depths that hemmed us in more than masthead high, with writhing slopes like the sides of mountains.
>
> The wind pitched itself at us with a force that made the gale of the night before seem puny and ineffective. Altogether it was an exhibition of violence unsurpassed. The nearest approach to it is afforded by Niagara Falls, as you ride up to the foot of the tumbling waters in the *Maid of the Mist*, or walk under them to the Cave of the Winds. But here both air and water were like a Niagara let loose and driving themselves down upon our little steel ship. Against the unprotected face the hard-driven spume stung like the flying particles of a sandstorm. It was terrible and magnificent.
>
> At 8 o'clock the barometer reached its lowest mark and stood at 28.58. From this point the mercury rose steadily and the wind tended to abate. The humming reverberation of the ship under the pounding seas gradually lessened and the general strain was relieved before night fell.
>
> The *Sherman* went into Nagasaki harbor and quarantine two days later, with Asiatic cholera among her crew and one death.

From September 10 to 12 the U. S. Navy transport *Pensacola*, from San Francisco for Manila, while in latitude 13° 30′ N., longitude 140°–135° E., experienced stormy weather and moderate southerly to westerly gales, with long rolling seas. On the 10th reports of a typhoon to the northwestward were received.

[1] Chicago Daily News, Oct. 20, 1919.

On the 21st and 22d a third typhoon prevailed off the coast of Japan. Very complete reports of this storm have been received from the American steamship *Venezuela*, Capt. G. W. Yardley, Yokohama for Honolulu, and the British steamship *Methven*, Capt. L. D. Douglas, Yokohama for Vancouver. The former vessel passed through the center of the storm from 3:10 a. m. to 4:15 a. m. of the 22d, latitude 35° N., longitude 150° 2′ E. The lowest barometer reading was 28.44 inches. On the 21st the *Methven* was found to be in the left-hand semicircle of this typhoon, proceeding on the same general course. The wind held steadily from the north for a considerable time, until the ship was hove to so as to permit the typhoon to cross her desired course to the eastward.

First Officer E. A. Winkworth, observer on the *Methven*, reports an interesting phenomenon, observed during the height of the storm. "A remarkable phenomenon of the sky at one period," says Mr. Winkworth, "was the appearance of a practically clear opening in the clouds, circular in shape and showing through as a light yellowish patch, its diameter covering an arc of 10° and its bearing from the ship in the direction of the storm field. The edges of this opening were torn and wild looking. This lasted for a considerable time, until a squall was experienced and it was not observed again."

Reports received are too few to permit of giving the exact paths of the typhoons.

NORTH AMERICA.

By A. J. HENRY.

The outstanding features of the weather seem to have been the breaking of the prolonged drought in the northern Rocky Mountains and Great Plains, and, in general, a reversal to some extent of the normal rainfall distribution for the month. Very little rain fell in the Gulf and South Atlantic States where heavy September rains are the rule. In the far Southwest a period of four days with light rains was the feature of the month. Temperature was generally above the normal. Pressure distribution was more or less irregular. The high pressure east of the Mississippi and south of the Ohio was probably closely associated with the shortage of precipitation in that region. Storm activity for the month was confined to the northern border, the Gulf of Mexico, and to Asiatic waters.

NORTH ATLANTIC OCEAN.

By F. A. YOUNG.

According to observations received from land stations, the mean pressure for the month of September was practically normal on the American coast north of Hatteras, and somewhat lower than usual south of that point, as well as in West Indian waters and the Bermudas; it was nearly normal in the British Isles and slightly above in the Azores.

At Greenwich mean noon on September 3 there was a slight depression central near Nantucket (see Chart IX) accompanied by light to moderate winds. According to

reports received from a number of vessels in that locality, this disturbance developed into a violent cyclonic storm a few hours afterwards, although it was of short duration and limited extent. Ensign Roger Brooks, United States Navy, who was attached to the U. S. S. *Zeppelin*, reported that the barometer began to fall at about 3 a. m. on the 3d, light southerly winds prevailing at the time. The barometer continued to fall until 3 p. m. when the lowest reading of 29.52 inches was observed. At 11 a. m. the direction of the wind was SSE. force 7, and increased in intensity to SW. by S., force 10, at 3:05 p. m. when the last rain squall occurred. The sky then cleared, with diminishing wind and rising barometer. During the height of the gale some seas came over the bows of this 15,000-ton ship, and the spray went over the tops of the funnels. The weather after 4 p. m. was sunny, with Cu.Nb. clouds about the horizon. At the time of the first heavy blow, the vessel was about 550 miles east of New York, while her position at Greenwich mean noon, September 3, was latitude 39° 44′ N., longitude 61° 15′ W.

Capt. R. C. Henderson of the British steamship *City of Oran* encountered the same storm and was not far west of the *Zeppelin*, as at local mean noon September 3 the position of his vessel was given as latitude 40° north, longitude 64° 31′ west. At 4 a. m. on the 3d the barometer read 29.98 inches; it then fell rapidly to 29.60 inches at 9:30 a. m., when the wind began to freshen. By 11 a. m. it was blowing a whole gale from the southeast, the barometer reading 29.15 inches, and by noon the wind had increased in intensity to over 90 miles an hour, and the barometer had fallen to 28.85 inches, which was the lowest reading recorded. During this period it was impossible to keep the ship headed into the wind with the engine turning ahead at full speed. After 1 p. m. the barometer began to rise and the wind to shift, gradually working around through the south to WSW. by 3 p. m. This caused a breaking sea which created considerable damage, as windows in the bridge shelter were blown in, one lifeboat smashed, and other minor injuries sustained. Capt. Henderson stated that while this storm was of short duration, the wind was the most violent he had ever experienced. As an illustration of its force, the hold ventilators were swaying like wind vanes, while on ordinary occasions it takes a man's full strength to turn them a little at a time. A number of other vessels sent in reports regarding this storm, but none of them apparently experienced as heavy weather as the *Zeppelin* and *City of Oran*.

At Greenwich mean noon on September 3, as shown on Chart IX, there was a second disturbance central near latitude 50°, longitude 25°, that was much greater in extent and duration than the one just described. A number of vessels near the center reported barometer readings of between 28.95 inches and 28.99 inches, and in the storm log the observer on board the American steamship *West Harcuvar* states: "Gale began on the 2d; wind southwest. Lowest barometer, 28.93 inches on the 3d; latitude 49° 02′ N., longitude 23° 15′ W. End of gale on the 5th; highest force 75 miles an hour; shifts of wind near time of lowest barometer, 12 points to northwest."

During the next 24 hours, as shown on Chart X, the western disturbance moved rapidly northeastward, and on the 4th the center was near St. Johns, Newfoundland, where the barometer reading had fallen from 30.20 inches on the 3d to 29.40 inches. Moderate southerly gales were reported in the easterly quadrants, while winds of less force were prevalent over the region south and west of St. Johns, with rain along the Canadian coast. On the 4th the center of the eastern LOW was near latitude 52°, longitude 20°, and while the barometer readings near the center were somewhat higher than on the previous day, strong gales still prevailed in the southern quadrants, as shown on Chart X.

From September 7 to 14 one of the most severe and protracted tropical hurricanes on record prevailed in the West Indies and Gulf of Mexico. This storm is described elsewhere (see pp. 664, 673), and Charts XI to XVIII show the general conditions at Greenwich mean noon of each day during its existence. Since the extremely low barometer readings reported were observed between Greenwich mean noon observations, the data on the charts do not show the minimum pressures or maximum wind velocities, especially as on some days there were comparatively few vessel reports received from localities where they were most needed.

On the 14th (see Chart XVIII) there were a number of vessels in the eastern part of the northern steamer lanes that encountered southerly gales of from 40 to 50 miles an hour. On the 15th one vessel near latitude 56°, longitude 28°, reported a westerly wind of over 60 miles an hour, but as no reports were received from other vessels in that locality, it was impossible to determine the extent of the disturbance.

On a number of different days during the remainder of the month widely scattered observations were received from vessels in the northeastern division of the ocean, indicating extensive areas of low pressure with winds of gale force, although not enough reports have been received up to date (October 31) for an accurate charting of the conditions in this region.

NOTES ON WEATHER IN OTHER PARTS OF THE WORLD.

British Isles.—The month was distinguished by great fluctuations in temperature, some daily readings being unusually high for the time of year and others equally low. Snow fell [about the 20th] over a large portion of North Britain, and sleet or hail in many southern districts. The general rainfall, expressed as a percentage of the average, was: England and Wales, 78; Scotland, 112; Ireland, 97.—*Symons's Meteorological Mag., Oct., 1919, p. 109.*

Argentina-Chile.—It has again been necessary to abandon the efforts being made to reestablish passenger traffic across the Andes over the sections of the Transandine Railway, which have been blocked by snow since May last.—*New York Sun, Oct. 13, 1919.*

DETAILS OF WEATHER OF THE MONTH IN THE UNITED STATES.

CYCLONES AND ANTICYCLONES.

By A. J. HENRY.

Rather more than the usual number of cyclones (15) appeared on the daily weather charts of September. While the predominating movement was eastward from the Canadian Northwest, there was a small number of secondary developments over the Plateau and Rocky Mountain regions and also over the middle portion of the North Atlantic, so that as a whole the movement was somewhat diversified. A single destructive tropical cyclone (Track No. IV, Chart III) moved into the field of observations. (See pp. 664–673, this REVIEW.) The second disturbance (see Track No. XVII) of apparent tropical origin at no time, so far as known, possessed the characteristics of a tropical cyclone. The feature of outstanding interest in connection with the movement of the severe tropical cyclone of the 6th–15th was the fact that it did not recurve to the northwest over the Gulf of Mexico. Evidently it skirted the southern border of the area of high pressure that encircles the globe in the vicinity of north latitude 30°, and was dissipated over northern Mexico.

Anticyclones.—Eight anticyclones have been plotted on Chart II, the majority of which first appeared over the Canadian Northwest or the Pacific off the California and Oregon coasts. The movement was eastward with a considerable southerly component in all cases.

THE WEATHER ELEMENTS.

By P. C. DAY, Climatologist and Chief of Division.

[Dated: Weather Bureau, Washington, Nov. 1, 1919.]

PRESSURE.

During the greater part of the first decade, pressure was moderately high over most eastern districts, and comparatively low from the Rocky Mountains to the Pacific. Normal pressures followed, except over the Gulf of Mexico, where the large and severe West Indian hurricane was. The remains of this storm moved into New Mexico September 14–17.

During the latter part of the second decade a low pressure area developed in the central Plains region and moved thence to the Great Lakes. This was followed by another early in the last decade. At the same time a wide area of high barometric pressure moved into the far Northwest and gradually overspread the central and eastern districts, reaching the Atlantic coast by the end of the decade. At the end of the month there were indications of a storm of some intensity off the south Atlantic coast.

The average pressure for the month (Chart VII, Tables I and III) was everywhere near the normal, but mostly below. Over most of the area east of the Mississippi and south of the Ohio Rivers the pressure was slightly higher than normal, save along the immediate Gulf Coast where the low pressure attending the tropical storm materially affected the average. From the Missouri Valley northward into Canada there was likewise an area with average pressure above the normal.

The prevailing winds (Chart VII, Tables I and III) were mostly from the south over the plains area from Texas to near the northern boundary, and in portions of the Mississippi valley and the Great Lake region. They were mostly from the northeast over the South Atlantic and east Gulf States, and from the northwest along the Pacific coast.

TEMPERATURE.

At the beginning of the month cool weather for the period of the year prevailed over the eastern portions of the country and in the far West, but in the Rocky Mountain region temperatures were much higher than normal. By the 3d, temperatures in the far Southwest had risen to considerably above normal, the maximum day temperatures at numerous points in Arizona and New Mexico ranging from 100° to 112° F. From the 5th to the 10th the highest readings of the month were recorded in all districts east of the Rocky Mountains, save over the Southeastern States where the highest temperatures occurred at the beginning of the second decade. In portions of the Lake region maximum temperatures about the 8th were the highest ever recorded in September. During this period temperatures remained moderately low in the far West, particularly in the central valleys of California where serious concern was felt over the slow ripening and drying of fruit.

The second decade opened with a general fall in temperature over the Missouri Valley, which gradually extended eastward, with the greatest changes over the more northern districts. By the middle of the decade temperatures in nearly all portions of the country had returned to near the normal for the season and remained so, with minor exception, throughout the remainder of the decade, save about the 18th, when sharp falls were observed in the northeastern districts and light to heavy frosts occurred at exposed points in New York and New England.

At the beginning of the third decade a strong high-pressure area was advancing into the North Pacific States and by the morning of the 22d had overspread the northern Rocky Mountain and adjacent districts, accompanied by the coldest weather of the month. Freezing temperatures prevailed over considerable areas, and the first severe frosts of the season were reported at exposed points from Montana and Wyoming to the eastern portions of Oregon and Washington. At the same time, summer temperatures were prevailing east of the Mississippi and much warmer weather had set in over the interior portions of California. With the eastward movement of the cold area the lowest temperatures of the month were very generally observed. Frosts or freezing temperatures were confined to limited areas over the more northern districts. Much needed warmth continued during the greater part of the decade in the large fruit districts of California. The maximum temperatures were frequently near 100° and the drying of prunes and raisins progressed under the most favorable conditions.

At the close of the month there had been a considerable drop in temperature over portions of the Great Lakes and in the far West, but elsewhere temperatures were near the seasonal normal.

Maximum temperatures for the month as high as 112° were reported from points in California and Arizona, and they ranged from 100° to 109° locally in practically all States from the Appalachian Mountains west to the Pacific. In the Lake region and generally over the northeastern States the maxima were slightly below 100° F.

Minimum temperatures were below freezing toward the end of the month over the more northern States, and in portions of the western mountains they were below 20° F., notably 9° and 3° F. in Wyoming and Montana, respectively.

For the month as a whole the average temperature was above normal practically throughout the country, and, while the departures from the normal were not generally large (see Chart IV), some sections had the warmest September in many years, notably 30 years in central Wyoming. In portions of the middle Plateau region September was the sixth consecutive month with mean temperature above the normal. In northern Michigan, however, it was the first month this year with a mean temperature below normal.

PRECIPITATION.

The month opened with showery weather along the Atlantic seaboard, and with local rains in the central Rocky Mountain and Plateau areas. During the following few days showers occurred in the extreme northeast and southeast sections, and also in the central Rocky Mountains and portions of the Missouri and upper Mississippi Valleys. However, the greater part of the first decade of the month was dry, except along the North Pacific coast, the extreme northern border and over the Florida Peninsula and locally along the Gulf coast.

The West Indian hurricane caused rain all along the immediate Gulf coast, then about the middle of the month it passed inland near the mouth of the Rio Grande. Figure 1, page 640, shows the rainfall of this storm in Texas and New Mexico, locally exceeding 9 inches. At the same time, showers were fairly general over the Great Lakes and the North Atlantic States.

During the latter part of the decade showers occurred in the Southwest and about the 18th a storm of considerable intensity moved from Kansas to the Great Lakes, accompanied by more or less general, and in some districts, heavy rains. A second rain area covered most of the country east of the Great Plains during the early part of the last decade, bringing heavy and well distributed precipitation to many sections where drought conditions had prevented preparation of the soil for fall seeding. The last few days of the month there was more or less precipitation in the West, and eastward to the Great Lakes. In parts of southern California the rains were remarkably heavy for the time of year; and effectually checked the forest fires, locally serious.

The precipitation for the month is shown on Chart V. In portions of the east Gulf States, where rain is usually abundant in September, the totals were mostly small and over large areas no appreciable precipitation occurred during the entire month. In portions of Virginia, the Carolinas, and Alabama it was the driest September in nearly 50 years; on the other hand in portions of Arizona and the Southwest the month was the wettest of record, and in Texas it was the fifth consecutive month with precipitation above the normal. Generally speaking, the precipitation was far below normal over all the Gulf States east of the Mississippi River and along the Atlantic coast from Virginia southward. There was generally a large excess from Texas to southern California, as well as from southern Nebraska to Lake Michigan, and over small areas in New England.

SNOWFALL.

Some snow was reported in the Rocky Mountain region as early as the 21st and considerable amounts fell in the higher elevations, particularly in the more northern districts during the last few days of the month. In Montana depths of 5 to 10 inches were reported from numerous points and falls of 2 feet or more were reported locally. In the high Sierra of California as much as 10 inches fell in a few localities.

RELATIVE HUMIDITY.

In New England and generally west of the Mississippi Valley, except in the far Northwest, the relative humidity was above normal, with unusually large departures from Texas westward and over portions of the middle Rocky Mountain and Plateau districts. From the middle Mississippi Valley eastward to near the Atlantic coast the atmosphere was relatively far drier than normal, a condition naturally resulting from the generally high temperatures and the absence of any considerable rainfall.

SEVERE STORMS.

The West Indian hurricane and two associated tornadoes are described on pages 639, 640, and 664–673.

Average accumulated departures for September, 1919.

Districts.	Temperature.			Precipitation.			Cloudiness.		Relative humidity.	
	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure from the normal.	General mean for the current month.	Departure from the normal.
	°F.	°F.	°F.	In.	In.	In.	0–10		P. ct.	
New England	60.6	−0.1	+14.3	4.42	+1.20	+2.21	6.2	+1.0	82	+1
Middle Atlantic	67.5	+1.6	+19.4	1.85	−1.50	−2.40	4.6	−0.1	75	+3
South Atlantic	73.7	+0.8	+ 9.0	1.59	−3.00	−4.30	3.5	−1.1	74	−7
Florida Peninsula	81.2	0.0	− 2.9	8.26	+0.30	+6.40	5.7	+0.2	78	−3
East Gulf	76.5	+1.7	+ 1.3	0.88	−3.00	+1.96	4.1	−0.4	72	−6
West Gulf	76.7	+1.0	− 7.5	4.01	+0.60	+3.10	4.9	+0.8	77	+8
Ohio Valley and Tennessee	70.5	+2.7	+12.1	1.70	−1.10	−2.20	4.1	−0.3	68	−6
Lower Lakes	64.7	+1.6	+18.7	2.23	−0.60	−0.90	5.4	+0.5	70	−4
Upper Lakes	61.6	+2.7	+29.7	3.06	−0.20	−3.20	5.9	+0.7	75	−3
North Dakota	59.1	+2.0	+29.2	0.90	−0.50	−2.35	5.1	+0.7	67	−2
Upper Mississippi Valley	68.4	+3.5	+21.4	4.16	+0.80	0.00	4.6	+0.2	71	−4
Missouri Valley	69.1	+4.2	+23.1	2.68	−0.10	−3.10	4.3	+0.1	67	−1
Northern slope	59.2	+1.8	+25.9	1.37	+0.30	−3.50	4.4	+0.3	62	+3
Middle slope	70.8	+3.3	+11.0	1.40	−0.60	−4.50	4.4	+1.0	64	+3
Southern slope	73.4	+0.6	−10.9	5.59	+3.00	+0.40	5.0	+1.4	70	+5
Southern Plateau	71.0	+0.5	+ 5.6	1.56	+0.60	+1.19	2.9	+0.4	51	+9
Middle Plateau	63.1	+0.7	+12.0	1.24	+0.60	−2.30	3.0	0.0	44	+2
Northern Plateau	60.8	−0.3	+14.7	0.94	+0.20	−2.70	3.5	+0.2	51	+1
North Pacific	59.0	+1.4	+10.2	2.34	−0.10	−4.80	4.6	−0.8	76	−3
Middle Pacific	63.4	− .1	− 5.4	0.77	+0.20	−1.80	3.5	+0.3	64	+1
South Pacific	68.1	0.0	+ 5.1	0.56	+0.40	−3.40	2.8	+0.1	69	+3

Winds of 50 mis/hr. (22.4 m./sec.), or over, during September, 1919.

Station.	Date.	Velocity.	Direction.	Station.	Date.	Velocity.	Direction.
Buffalo, N. Y	19	74	sw.	Modena, Utah	6	56	sw.
Do	20	62	sw.	Mt. Tamalpais, Calif	3	66	nw.
Do	24	56	sw.				
Do	25	56	sw.	Do	4	68	nw.
Corpus Christi, Tex	14	72	ne.	Do	5	62	nw.
Do	15	70	se.	Do	6	70	nw.
Del Rio, Tex	15	58	e.	Do	27	54	sw.
Galveston, Tex	14	53	e.	North Head, Wash.	30	72	s.
Houghton, Mich	20	63	nw.	San Antonio, Tex.	15	52	se.
Key West, Fla	9	100	e.	St. Paul, Minn	26	51	s.
Do	10	110	e.	Toledo, Ohio	19	64	s.

SPECIAL FORECASTS AND WARNINGS. WEATHER AND CROPS.

WEATHER WARNINGS, SEPTEMBER, 1919.

By H. C. FRANKENFIELD,

Supervising Forecaster.

[Dated: Weather Bureau, Washington, Oct. 22, 1919.]

Except for the West Indian hurricane described in detail below, there were no storms of consequence during the month, and the few warnings that were ordered on the Great Lakes and along the Atlantic coast failed for the most part of verification.

FROST WARNINGS.

On the morning of the 4th, with high pressure over Minnesota and the upper Lake region, possible light frosts were forecast for the following morning over upper Michigan, but the forecast was verified over the eastern portion only, low pressure approaching rapidly from the Northwest. On the morning of the 13th high pressure and comparatively low temperature prevailed over the Lake region and the Ohio Valley, with low pressure to the eastward, and local frosts were forecast for the following morning in New England and the Middle Atlantic States. However, the rise in pressure ceased and there were no frosts. The frosts on the morning of the 18th over northeastern New York and New England were forecast.

On the morning of the 25th there was a well-marked disturbance over central Ontario, with rapidly rising pressure to the westward, and frosts were forecast for Michigan on the following morning. These warnings were verified, the frost having been heavy in some localities. Frost was then forecast for the morning of the 27th for New England, New York, and the extreme northern portions of New Jersey and eastern Pennsylvania, and these forecasts were also verified.

AVIATION FORECASTS.

Special aviation forecasts were made for the Army and Navy balloon race on the 26th and for the National balloon race on October 1, both from St. Louis, Mo., and also for the early days of the recruiting tour of the United StatesNavy hydroplane, *NC 4*.

THE WEST INDIAN HURRICANE OF SEPTEMBER 6-14, 1919.

BEGINNINGS OF THE CYCLONE.

So far as observational data are concerned, the exact genesis of the tropical storm of September 6–14 is somewhat shrouded in doubt. Although not in strict accordance with the normal behavior of previous storms, it appears to be a reasonable assumption that this storm owed its inception to a redevelopment of the minor disturbance that was first noted on the evening of September 2 in the vicinity of latitude 17° or 18° north and longitude 63° west, or a little west of the island of Antigua. This first, or minor, disturbance, moved west-northwestward at about a normal rate, passing near the southern portion of the island of Porto Rico, and by the evening of the 4th it had reached the north coast of the island of Santo Domingo with a barometer reading of about 29.80 inches. On the morning of the 5th the center of the disturbance was approximately 100 miles southwest of Turks Island with about the same barometric pressure, and with an east wind at Turks Island, and light southwest winds at Puerto Plata. By the evening of the 5th the winds at Turks Island had changed from east to west, and were southerly over Santo Domingo and Haiti, still light in character, apparent evidence that the disturbance had recurved to the northeastward during the day, and that it was moving in that direction in very moderate form. At this writing no details regarding this storm have been received. Special observations taken at 2 p. m., September 3 at St. Thomas, Virgin Islands, and San Juan, P. R., showed a maximum wind velocity of 48 miles an hour from the southeast at the former, and of 32 miles an hour from the east at the latter place, but no other strong winds were reported until the morning of the 6th, when Turks Island reported a maximum wind velocity of 30 miles an hour from the south during the night.

THE HURRICANE IN SOUTH FLORIDA.

On the evening of the 6th pressure and wind conditions over Santo Domingo and the Bahamas indicated the possible presence of a disturbance over the eastern Bahamas. Conditions were slightly more pronounced on the morning of the 7th, and special observations were called for from Nassau and from Miami, Fla., the message stating that there were slight indications of a disturbance over the central Bahamas. However, no afternoon report was received from Nassau, and the evening report was not received until 9 a. m. of the 8th, about 12 hours late. By this time the wind at Miami was blowing 26 miles an hour from the northeast, with slowly falling pressure, and it became apparent that the storm was one of considerable intensity. Accordingly at 10 a. m. northeast storm warnings were ordered on the Florida coast from Jupiter to Key West, and thence northward on the west coast to Fort Myers. At the same time the usual advices were sent to all interests along the Atlantic and Gulf coasts, and special observations were ordered taken at frequent intervals during the day. Hurricane warnings were ordered displayed at 1 p. m. from Jupiter to Key West, the order reading as follows:

> Change to hurricane warnings 1 p. m. Jupiter to Key West. Delayed report from Nassau, barometer 29.46 and wind 56 miles from northeast. Storm center will probably reach south Florida coast by to-night, attended by dangerous northeast winds. Caution all vessels to avoid the Florida Straits and the east Florida coast until further notice.

At 2 p. m. northeast storm warnings were ordered at Tampa, Fla., for strong winds in that vicinity, and all shipping cautioned to delay until the storm had passed. Emergency warnings for dangerous winds were also given the widest possible distribution throughout southern Florida.

At 1 p. m. of the 9th hurricane warnings were continued at Key West and changed to northeast storm warnings from Jupiter to Miami. The northeast warnings were also continued on the west Florida coast north of Key West to Tampa. At 9 p. m. of the 9th the following special warning was issued:

Tropical disturbance 4 p. m. apparently over Florida Straits, a short distance south of Key West with greatly increased intensity, and probably moving northwest. It will enter the Gulf of Mexico Tuesday night and continue its northwestward movement. All Gulf shipping north of latitude 25° warned to avoid the probable path of the storm.

The storm center passed about 30 or 40 miles south of Key West about midnight of September 9. At this time the barometer at Key West read 28.83 inches with an east wind of an estimated velocity of 105 miles an hour, which increased slightly during the next hour. At Sand Key the lowest barometer at about the same time was 28.35 inches, a difference of 0.48 inch within a distance of 8 miles.

THE STORM AT KEY WEST AND VICINITY.

The following report on the storm at Key West and vicinity was prepared by Mr. H. B. Boyer, official in charge of the Weather Bureau office at that place:

"The storm that passed over Key West on September 9 and 10 was, without question, the most violent experienced since records at this station began. While the minimum barometric reading, 28.81 inches, was not as low as that recorded in 1909 (28.52) and in 1910 (28.47), the violence of the wind was undoubtedly greater. It is to be regretted that owing to the vibrations of the tower supporting the wind instruments the anemometer cups were shaken loose and blown away at 7:30 p. m. on the 9th in gusts ranging between 75 and 80 miles an hour, and thereafter until 3:35 p. m. of the 10th the wind-velocity record was lost. The wind-vane was blown away at 12:45 a. m. of the 10th during the winds of greatest intensity, and at 3:16 a. m. the collector of the recording rain-gage was blown off and the door forced open. The thermometer shelter held and temperature data are unbroken. In estimating the lost data great care has been taken, advantage having been taken of notes made throughout the storm, and further advantage taken of the fact that the official in charge has experienced five hurricanes, which enables him to make a fairly accurate comparison.

"The first warning was received on the 8th at 9:55 a. m.:

"Hoist northeast storm warning 10 a. m. Jupiter to Key West and at Fort Myers, Fla. Disturbance near or over southwestern Bahamas apparently moving west-northwest. Strong northeast winds Monday, and will probably increase to gale force. Advise great caution until further advices later in the day.

"Storm warnings were immediately displayed, and the information disseminated.

"At 1.05 p. m. the following was received:

"Change to hurricane warnings 1 p. m. Jupiter to Key West. Delayed report from Nassau: Barometer 29.46 and wind 56 miles from the northeast. Storm center will probably reach south Florida coast to-night attended by dangerous northeast winds. Caution all vessels to avoid the Florida Straits and the east Florida coast until further advices.

"Hurricane warnings were immediately displayed and the information disseminated by every available means. The response to this warning was immediate and there followed a period of great activity, especially as regards shipping. Vessels were moved to safer anchorage or better secured, and all weak places in residences and buildings of all descriptions were strengthened as much as possible by nailing and battening doors, windows, roof hatches, etc. In the terrific gusts that prevailed during the height of the storm stanch brick structures had walls blown out and large vessels, firmly secured, were torn from their fastenings or moorings and blown on the banks. Notwithstanding the great loss, estimated at $2,000,000, the official in charge has been the recipient of many congratulations on the splendid service rendered by the Bureau.

"Owing to the very slow progressive movement of the storm in this vicinity, winds of gale force and over lasted continuously from about 7 a. m. of the 9th to about 9:30 p. m. of the 10th. The apex of the hurricane was reached on the 9th at midnight when the center, moving slowly west-northwest, was south of and nearest the station. The center when at its nearest point was probably about 30 or 40 miles distant.

"Following is an hourly tabulation covering the period during which winds of gale force prevailed:

	Barometer.	Wind direction.	Maximum velocity.	Weather.
SEPT. 9.	*Inches.*		*Miles per hour.*	
7 a. m.	29.61	ne.	36	Light rain.
8 a. m.	29.61	nne.	38	Do.
9 a. m.	29.58	n.	36	Threatening.
10 a. m.	29.56	nne.	39	Light rain.
11 a. m.	29.54	ne.	40	Do.
12 noon	29.50	ne.	37	Do.
1 p. m.	29.46	ne.	42	Do.
2 p. m.	29.40	ne.	44	Moderately heavy rain.
3 p. m.	29.31	ne.	48	Do.
4 p. m.	29.27	ne.	50	Do.
5 p. m.	29.22	ne.	54	Do.
6 p. m.	29.13	ne.	58	Do.
7 p. m.	29.08	ne.	58	Heavy rain.
8 p. m.	29.05	ne.	70	Do.
9 p. m.	28.99	ne.	[1] 80	Do.
10 p. m.	28.97	ne.	[1] 85	Do.
11 p. m.	28.93	ne.	[1] 90	Do.
12 midnight	28.81	e.	[1] 105	Do.
SEPT. 10.				
1 a. m.	28.90	e.	[1] 110	Do.
2 a. m.	28.96	e.	[1] 100	Do.
3 a. m.	29.02	e.	[1] 90	Do.
4 a. m.	29.07	e.	[1] 85	Do.
5 a. m.	29.13	se.	[1] 80	Do.
6 a. m.	29.20	se.	[1] 70	Do.
7 a. m.	29.26	se.	[1] 70	Do.
8 a. m.	29.35	se.	[1] 70	Do.
9 a. m.	29.39	se.	[1] 60	Light rain.
10 a. m.	29.44	se.	[1] 55	Do.
11 a. m.	29.46	se.	[1] 50	Do.
12 noon	29.50	se.	[1] 48	Do.
1 p. m.	29.53	se.	[1] 48	Do.
2 p. m.	29.52	s.	[1] 45	Do.
3 p. m.	29.56	s.	[1] 40	Do.
4 p. m.	29.57	s.	[1] 40	Do.

[1] Estimated.

"From the forenoon of the 9th squalls of wind and rain progressively increased in force and frequency, culminating in terrific gusts of great violence between midnight of the 9th and 2 a. m. of the 10th. As the storm's center slowly passed into the Gulf of Mexico to the westward the squalls and gusts gradually became less violent and of less frequency.

"The usual phenomena preceding, accompanying, and following storms of tropical origin were present in this one; and while no thunder was heard, diffused lightning was noted at intervals for several hours before the maximum force was reached.

"As previously stated, the property loss is estimated at $2,000,000, the air station alone losing about $800,000. Probably not a structure on the island escaped being damaged more or less, the Weather Bureau building and grounds suffering quite badly. Three lives were lost by drowning.

"The rainfall was extremely heavy and continuous. The loss of rainfall record is unfortunate, but from the partial record obtained and from notes made the total amount is estimated at 13.39 inches, the heaviest occurring during the early morning hours of the 10th.

"The demands made on the office force were beyond their ability to perform, but every effort was made to meet all emergencies. What with the duties of the station, answering the constantly ringing telephone, giving advice and information to callers, and throughout the night of the 9th–10th working to make the building more secure, the strain came near the breaking point. The official in charge had no sleep from the morning of the 8th until the night of the 10th, and this is also true of Assistant Observer J. C. McCarthy, whom I commend without reserve for giving unstinted support throughout the period of stress.

Through the courtesy of Admiral Benton C. Decker, commandant seventh naval district, who placed the motor sailer of the gunboat *Wheeling* at my disposal, I proceeded to Sand Key on the 12th to look after the welfare of the employees at that station and to inspect the station. As the island was completely washed away and seas breaking over, a landing was impossible. Repairman Saunders swam out and piloted us in to a point near the lighthouse, where the sea was comparatively quiet. The personnel were found safe. As previously instructed, they had abandoned the Weather Bureau building and gone to the lighthouse for greater safety. The 85-foot tower had buckled about 20 feet above the foundation pillars and fallen across the south side of the building, which was intact and but little damaged. The four cisterns are gone, and also the steps; most of the brace rods are badly bent. The motor boat was swept away and lost. I am informed by Repairman Saunders that as the interior of the Weather Bureau was found in so much better condition than the lighthouse quarters the men returned to it by wading and swimming and immediately entered upon the duties of vessels reporting. All instruments exposed in the open were blown or washed off."

The report of the storm experiences at Sand Key, Fla., was prepared by Mr. Eugene M. Barto, observer, and is as follows:

The first warning of the hurricane was received Monday noon, when the northeast storm warnings were changed to hurricane warnings. Instructions were received to take no chances whatever, so preparations were begun in case it became necessary to move to the lighthouse.

The barometer fell steadily and the wind increased during the night (p. m.) of the 8th and night (a. m.) of the 9th. After a squall which ended at 4:30 a. m. we began moving the extra instruments, records, flags, telescope, typewriter, bedding, etc. This continued until 1 p. m., when the station was closed and abandoned. The noon observation of the 9th was the last one taken. The velocity of the wind was 65 miles an hour and rain was falling, thus making it impossible to see more than 100 yards away.

The hurricane warning flags were blown down at 3:30 p. m. The rain gage was washed away about 6:30 p. m. by the waves, which completely covered the island. The motor boat which had been doubly secured to her moorings broke away at 7 p. m. The instrument shelter was badly damaged and wedged in the tower of the building at 7:30 p. m. At 8 p. m. the waves washed away the shed under the Weather Bureau, together with the ice chest and five cans of carbide. Shortly after this the four water-tanks were broken up and washed away. Two of the cement platforms upon which the tanks rested were washed off their pillars while a third was damaged by the waves.

The storm warning tower was blown down shortly after 10 p. m., breaking off at a height even with the roof of the building, thus extinguishing the hurricane warning lights. The tower fell on the south side of the building, broke all three lights, tore up the roofing, and tore away one-half the cornice. One of the four sides of the cement support of the storm warning tower which rests upon pillars was forced and badly cracked, part of which has already fallen down.

The iron steps of the building were broken away and washed about 30 feet. Two iron collars around a pillar of the building were broken by something washing against one of the braces.

The record showed that the anemometer cups blew away at 9:35 p. m. with a wind velocity of 84 miles an hour. The wind vane was probably blown away shortly after midnight. This was also the time of the lowest barograph record, which was 28.35.

A window casing of the lighthouse was blown in, thus exposing the typewriter to the salt water which rendered it useless.

The storm continued during Wednesday and Thursday, the wind and rain making it impossible to see vessels. Watches were resumed Thursday morning, September 11, at daybreak and signal work was carried on from the lighthouse until 10 a. m. Friday morning, when it was again resumed at the Weather Bureau.

Friday and Saturday were spent in transferring articles from the lighthouse to the Weather Bureau by means of rope stretched from one building to the other. This method was necessary because the water was several feet deep on the island.

The instruments were taken care of, wires tested, and the building cleaned and put in order. The extra anemometer was put up at midnight Sunday and the extra sunshine recorder Monday morning. Observations were resumed at 8 a. m. Monday, September 15, 1919. The instrument shelter was put in serviceable condition on the 16th and the thermometers were exposed at midnight.

Details of barometer, wind, and rain observations follow:

The barometer reading at 8 p. m. of the 8th was 29.77, reduced, and the wind velocity was 36 miles an hour from the north. The barometer fell steadily during the night, while the wind, which continued in the north, increased. The barometer reading at 8 a. m. of the 9th was 29.59, and the wind velocity 50 miles an hour from the north. The barograph showed a steady fall until 12.10 a. m. of the 10th, when it reached its lowest point, 28.35. It rose steadily throughout the 10th, showing a record of 29.66 at midnight. The prevailing wind direction was north until 12 noon of the 9th, when it shifted to the northeast. It continued in this direction until 10.10 p. m., when it changed to south. It later shifted to the southeast at 10.46 p. m., and at 12.17 a. m. of the 10th shifted to the east, at which time the wind vane probably blew away. The wind increased rapidly, reaching a maximum velocity of 65 miles an hour from the northeast at 12.48 p. m. of the 9th, after which higher velocities were registered at intervals until the highest was recorded, which was 94 miles an hour from the northeast at 8.39 p. m. The hourly wind movement from 2 to 3 p. m. was 77 miles; from 3 to 4 p. m., 76 miles; from 4 to 5 p. m., 59 miles; from 5 to 6, 57 miles; from 6 to 7 p. m., 64 miles; from 7 to 8, 77 miles; from 8 to 9 p. m., 84 miles, and from 9 to 9.35 p. m., 50 miles, at which time the instrument blew away.

A trace of precipitation fell on the 8th between 11.20 and 11.35 p. m. During a squall between 3.15 and 4.35 a. m. of the 9th, 0.36 inch fell. Rain again began to fall at 9.25 a. m. and continued until the night of the 10th. The amount could not be determined because the rain gage was washed away by the waves.

Below is given a portion of the log of the steamship *Winona*. It will be remembered that the *Winona* went ashore near the Pulaski Shoals at the northeast portion of the Dry Tortugas group, her master having been unable to determine his position on account of the storm.

Log of steamship Lake Winona (Capt. Roper), from New Orleans, La., to San Juan, P. R.

SEPTEMBER 9, 1919.

4:00 a. m. Fresh breeze and a moderate sea. Cloudy, with passing rain squalls.

6:00 a. m. Strong breeze, increasing fast.

7:10 a. m. Half speed; hove to on port bow; half gale blowing, with heavy rain squalls; high seas running; heading ENE., making little headway.

1:00 p. m. Boatswain broke left leg catching same in starboard galley door with intention of closing it.

3:00 p. m. Blowing a gale of wind. Part of bunker coal on forward deck washed overboard. Going slow astern. Hurricane blowing. Second mate had leg cut seriously. Wind changeable from northeast to northwest, blowing a hurricane; 90 miles an hour; riotous sea running, and half speed ahead; ship behaving well in sea, but not steering. Squally and terrific wind blowing from northwest; drifting to the eastward; ship not steering.

SEPTEMBER 10, 1919.

1:00 a. m. Heavy sea running, with terrific squalls of long duration; ship not steering; force of wind about 125 miles an hour; drifting to the northward and eastward.

6:00 a. m. Heavy sea running with terrific wind of hurricane force; making northeasterly course; ship not steering. At 10 a. m. ship struck reef, but not knowing what position or reef could be on account of having no observation since 8th. Got port boat ready in case of necessity, swung out and lashed to rail. Two men went in to bail out same. Wind veered around to northwest; heavy sea returned, hitting bow of lifeboat, which broke forward ring. Another sea struck lifeboat, lifting her out of water, parting painter; men climbed to stern of lifeboat and in doing so tripped stern hook, leaving boat free to drift away; tried to throw them lines, but boat drifted too fast. A. B. sailor named Edward Puretto and Andrus Pulvels, O. S., were in the lifeboat and were lost with it; 12 noon. During this time of ship's striking reef the pipe connections between port and starboard boilers broke, rendering useless. Ship pounding heavily, with seas breaking over her. Let go starboard anchor and opened tank valves to fill same and keep ship steady. Port anchor not working through windlass being strained by pounding of heavy seas. Toward sundown wind moderated, with rising barometer.

Steamer Lake Winona.

	Wind direction.	Pressure.		Wind direction.	Pressure.
SEPTEMBER 9.			SEPTEMBER 10—con.		
4 a. m.	ne.	29.78	9 p. m.		27.80
6 a. m.		29.70	10 p. m.	se.	
7 a. m.	ne.	29.68	12 midnight	se.	
8 a. m.	ne.	29.64			
9 a. m.	ne.		SEPTEMBER 11.		
10 a. m.		29.50			
12 m.	n.	29.40	3 a. m.	se.	27.90
4 p. m.	n.	27.70	7 a. m.	se.	
8 p. m.	n.	27.55	10 a. m.	se.	27.96
12 midnight		27.45	3 p. m.	se.	28.40
			7 p. m.	se.	
SEPTEMBER 10.			11 p. m.	se.	28.45
1 a. m.	nw.	27.60	SEPTEMBER 12.		
4 a. m.	nw.	27.55			
8 a. m.	se.	27.50	2 a. m.		29.20
10 a. m.	se.	27.55	6 a. m.	se.	
11 a. m.	nw.		8 a. m.		29.40
2 p. m.	nw.	27.80	1 p. m.		29.60
4 p. m.	nw.		6 p. m.	se.	29.86
6 p. m.	se.				

IN THE GULF.

With one or two unimportant exceptions no reports were received from the Gulf of Mexico after the morning of the 10th until after the storm had passed into Texas, which was during the day of the 14th. It was therefore absolutely impossible to forecast the intensity and progress of the storm, and the coast stations, far from the center of the storm, afforded but meager information.

During the afternoon of Wednesday, September 10, the northeast warnings at Tampa were ordered continued for another day for strong winds off the coast, and at 10:30 p. m. northeast warnings were ordered along the Gulf coast from Carrabelle, Fla., to New Orleans, La., the message reading as follows:

Hoist northeast storm warning 10:30 p. m. Tropical storm probably about latitude 26°, longitude 85°, moving northwest. Dangerous winds Thursday over southeast Gulf, and increasing northeast winds over central and northeast Gulf, probably becoming strong on coast by Thursday night. While exact location and movement of storm can not now be determined, every precaution should be taken against dangerous winds on the coast within 36 hours.

After this time the exact path of the storm center was conjectural, and at 4 p. m., September 11, the following warning was issued:

Hoist hurricane warning 4 p. m. Louisiana coast to Carrabelle. Tropical storm in north-central Gulf of Mexico, still moving northwest, probably near latitude 27 and longitude 87. Will likely reach middle Gulf coast to-night, and warnings of Wednesday night to take every precaution against dangerous winds repeated.

147217—19——5

Vessel reports received by mail some time afterwards indicated that the position given above was a little too far north of the storm center, perhaps as much as 1°. At the same time emergency warnings were issued for inland points in extreme northwestern Florida and the southern portions of Alabama, Mississippi, and Louisiana.

At 9 p. m., September 11, northwest storm warnings were ordered along the Texas coast from Port Arthur to Velasco.

In the absence of definite information and in the hope that even a single radio report might be received from the Gulf, no further advices were issued until after the receipt of special observations in the early afternoon of September 12, when the following telegrams were given widespread distribution:

Observer, New Orleans, La.:

Continue hurricane warning Louisiana coast. No further definite information regarding storm. Now probably near latitude 27° 30′ and longitude 89°. Further advices to-night: also earlier if any definite information received. Warnings changed to storm northeast Mobile and Pensacola, and hurricane warnings continued Mississippi coast.

Displayman, Bay St. Louis, Pass Christian, Gulfport and Pascagoula, Miss., and Observer, Mobile, Ala., and Pensacola, Fla.:

Continue hurricane warning 4 p. m., Bay St. Louis to Pascagoula, and change to storm northeast warning Mobile and Pensacola. No radio reports to-day. Storm center probably now near latitude 27° 30′ and longitude 89°. Further advices to-night; also earlier should any definite information be received.

At 5:53 p. m. the following was also widely disseminated:

Four p. m. reports indicate probability of storm reaching east Louisiana coast to-night.

Later reports indicated that this probability did not become a fact. However, the statement had not been put forth as conclusive, and at 7:30 p. m. special 10 p. m. observations were called for and instructions issued to request the Gulf coast telegraph offices to remain open until later advices could be received. These were sent at 11:30 p. m., as follows:

Regret that no radio reports were received from Gulf of Mexico during the entire day. Increasing northeast winds at mouth of Mississippi River indicate that storm is not far to southward of that locality, and we can only repeat previous messages urging great caution until further advices Saturday morning. Good night.

The morning observations of September 13 at coast stations did not present any reasons for a change in the advices of the previous night, and information to that effect was issued. The barometer at the mouth of the Mississippi River had fallen 29.60 inches, and a 40-mile southeast wind was blowing, increasing to 53 miles an hour about 7:30 p. m.

The 8 p. m. observations of the 13th were the first to afford any indication that the Louisiana coast would likely escape the full violence of the storm, and after the receipt of 10 p. m special observations the following warning was put forth at 11:30 p. m.:

Disturbance apparently central in Gulf south of Galveston. Barometer on coast steady, with slight rising tendency last two hours and is low over entire west Gulf. As center of disturbance can not be located, watch barometer carefully during night, and take all possible precautions against rising winds and higher tides, especially if barometer begins to fall steadily.

Some hours previously northwest storm warnings had been extended to cover the entire coast of Texas.

On the morning of September 14 the storm center was not far from the coast of Texas, between Corpus Christi and Brownsville, and during the day it passed inland, with marked although with steadily diminishing intensity.

REPORT FROM NEW ORLEANS.

Advisory messages relative to the tropical disturbance, warning all shipping to avoid the probable path of the storm, began to be received at New Orleans on the 8th, when the disturbance was over the western Bahamas, and these warnings were distributed to West Gulf shipping points and display stations.

On the 10th at 9:30 a. m. we advised all vessels at Louisiana coast points to remain in port, and small-craft warnings were displayed to prevent fishing vessels from venturing far from shore.

On Wednesday, September 10, at 10:40 p. m. northeast storm warnings were displayed at New Orleans and elsewhere in extreme southeastern Louisiana, increasing northerly winds being predicted for Thursday. This warning was extended westward to Morgan City on the 11th at 9 a. m.

Hurricane warnings for the Louisiana coast were ordered by the Washington office at 4 p. m. on the 11th, and shortly afterwards emergency warnings "to notify all interests to take every precaution against dangerous winds to-night and Friday" were received from Washington. These warnings were given the widest possible distribution. In addition to the warnings sent to the usual lists at Government expense they were carried by boats to Barataria Bay and Grand Isle. A boat was hired at Lake Charles, and the warning was disseminated by this means to the isolated sections of Cameron Parish in the extreme southwestern portion of the State. The telegraph and telephone companies and the Louisville & Nashville Railroad Co. kindly cooperated in the distribution. The city government and the press at New Orleans and elsewhere also gave wide distribution to the warnings.

The following warnings were issued from New Orleans:

SEPTEMBER 11, 1919.

Hoist northwest storm warning 9 p. m. Port Arthur to Velasco, Tex. Tropical disturbance now over north-central Gulf will probably cause increasing northerly winds on east coast of Texas Friday and caution advised.

SEPTEMBER 12, 1919.

Hoist northwest storm warnings 9 a. m. Texas coast west of Velasco to Corpus Christi. Change to northeast warnings Port Arthur to Velasco. Tropical disturbance in Gulf will cause increasing northerly winds next 24 hours, probably reaching gale force. Precautions should be continued.

The hurricane warnings on the Louisiana coast were continued at 4 p. m. on the 12th on orders from Washington, and this warning also was thoroughly distributed Later we were advised from Washington that the 4 p. m. reports indicated the probability of the storm reaching the Louisiana coast that night, and another message, received at 11:05 p.m., stated that increasing winds at the mouth of the Mississippi River indicated that the storm was not far southward of that locality.

The wind at Burrwood, La., at the extremity of Southwest Pass, an outlet of the Mississippi, increased considerably on the night of the 12th–13th; at 7 a. m., a velocity of 40 miles an hour from the southeast was reported, and the barometer at 29.60 was 0.10 lower than 12 hours before. A moderate but increasing wind from the east prevailed at New Orleans at this time with intermittent rain gusts of higher velocity.

The following was received from Washington September 13, at 11:15 a. m.:

Advisory: Tropical storm now close to east Louisiana coast, apparently maintaining northwest movement, but with evidences of recurving. Will cause dangerous easterly gales eastern Louisiana and southern Mississippi and strong easterly winds southern Alabama and extreme northwest Florida, beginning this afternoon. Winds will shift to southeast and south by Sunday morning.

These warnings were distributed fully, and conditions up to 2 p. m. of the 13th tended to confirm them, for the tide continued to fall slowly at Galveston, Tex., but increased to a marked degree along the Louisiana coast. The tide was 6 feet above normal on Lake Borgne and on Grand Isle, and 5 to 6 feet above normal on Lake Pontchartrain, on the afternoon of the 13th. The Louisville & Nashville train schedule was annulled on account of water over the track near Lake Borgne. The tide overflowed the resorts at Spanish Fort and Bucktown, on Lake Pontchartrain, to a depth of a few feet and caused damage to the extent of a few thousand dollars. At Grand Isle the salt water covered the cultivated land to a depth of 1 foot and ruined the cauliflower crop, valued at $30,000. Fresh to strong gales continued at Burrwood throughout the 13th, the highest velocity being 53 miles an hour, at 7:26–7:31 p. m. Strong winds prevailed at New Orleans, mostly from the east, but for short periods from the southeast.

Storm warnings on the Texas coast were changed from northeast to northwest, as follows:

SEPTEMBER 13, 1919.

Change to northwest storm warning 9 a. m., Port Arthur to Velasco, Tex. Tropical disturbance moving into Louisiana west of mouth of Mississippi River will cause strong northerly to westerly winds on east coast of Texas, with moderate to fresh northerly gales on extreme east coast.

During the afternoon of the 13th, special observations showed slowly falling barometer on the Texas coast, with some increase in the tide and the southeast swells at Galveston, and the following warning was issued:

Hoist northwest storm warning 6:30 p. m., Texas coast west of Velasco to Brownsville. Tropical disturbance in Gulf will cause increasing easterly to northerly winds, probably gales, on Texas coast Saturday night. Change to northeast storm warning Port Arthur to Velasco. Further advices later. Rising tide.

The following message was sent at 11:30 p. m. on the 13th direct from Washington to Port Arthur, Galveston, and Corpus Christi:

Disturbance apparently central in Gulf south of Galveston. Barometer on coast steady, with slight rising tendency last two hours and is low over entire west Gulf. As center of disturbance can not be located, watch barometer carefully during night and take all possible precautions against rising winds and higher tides, especially if barometer begins to fall steadily.

We were advised by the Galveston office next morning that warning to take protective measures was spread over the entire Texas coast at midnight.

As soon as the morning reports from the Texas coast were received, the following warning was sent to Texas coast stations and displaymen:

Advisory, 8:20 a. m.: Gulf storm now near south coast of Texas. Continue all precautions Sunday and Sunday night against dangerous winds and high tides from mouth of Sabine River to Brownsville.

Points on the Louisiana coast were advised of this warning and were notified that there was no further danger on the Louisiana coast.

The 10 a. m. (eastern standard time) report from Corpus Christi showed a barometer reading of 29.14, with a north wind of 36 miles an hour and a maximum velocity of 48 miles an hour from the north. The San Antonio and Houston offices were advised promptly that the storm center was near Corpus Christi and the barometer reading at 10 a. m. was given them. The 1 p. m. and 3 p. m. special observations, which had been called for, were not received from Corpus Christi on account of the wires being down. At 7:50 p. m. the following message was sent to Galveston and Port Arthur:

Storm passed inland near Corpus Christi, where barometer 29.14 at 10 a. m. Warnings may be lowered after gale subsides.

Central standard time is used in this report except in the reference to special observations at Corpus Christi.—*R. A. Dyke.*

CONDITIONS AT GALVESTON.

This storm caused high winds and tides in the Galveston district. Fortunately, we were able to take precautions to some extent in this district, especially in the vicinity of Galveston, and the damage resulting from the storm was largely reduced to a minimum.

The storm was first reported on September 3, 1919, "near and south of Porto Rico," and bulletins showing the progress of the storm were received daily, except on September 6 and 7. These bulletins were given a wide and effective distribution by means of the press, the telephone, telegraph, and the radio.

The storm entered the Gulf on September 9, and the first effect of the storm noted at Galveston was a slight, regular swell from the southeast that began to appear on the night of the 10th about 7 p. m. A light haze that developed about 2 p. m. the 10th continued until the lower clouds that formed late on the afternoon of the 13th finally did away with the hazy condition. Cirrus clouds coming from the tropical storm made their appearance on the morning of the 11th and continued until the lower clouds finally obscured them. These cirrus clouds were observed moving generally from the southeast. On the 13th alto-cumulus, moving mostly from the northeast, were the predominating upper clouds. During the afternoon of the 13th strato-cumulus clouds made their appearance, and by sunset the sky was practically covered by these lower clouds. From this time these lower clouds continued until the storm was over, interspersed with quickly moving scud.

A moderate rainfall accompanied the storm, a trace falling on the 13th shortly after 7 p. m., and showers on the 14th, 15th, and 16th, the total rainfall for the storm amounting to 2.35 inches.

Northerly winds prevailed on the 10th, 11th, 12th, and 13th. At times on the 10th and 11th the wind was from the northwest, and from the northeast on the 12th. During the morning of the 13th the wind prevailed from the north, but with a northeast tendency. By 2 p. m. on the 13th the wind was definitely from the northeast, and continued so until the wind shifted to easterly at about 6 a. m. on the 14th. At 2 p. m. on the 14th the wind shifted to southeast, continuing from this direction until the storm was over.

The winds were generally light until the 12th, when moderate winds prevailed during the afternoon and night. During the 13th the winds ranged from moderate to fresh, becoming strong by mid afternoon. Verifying velocity, 32 miles per hour, was first reached at 4.23 p. m. and continued with slight lulls until about 4 a. m. on the 15th. The maximum velocity reached during the storm was 53 miles from the east at 7.23 a. m. on the 14th, the extreme velocity being 60 miles.

The regular diurnal fluctuations of the barometer was present during practically the entire period of the approach of the storm, though the fall was more pronounced than the rise. The barometer had fallen below normal by the 10th and reached its lowest point at 4.30 a. m. on the 14th with a reading of 29.58 inches. On the night of the 12th there was a rather marked increase in the barometer reading, probably caused by the southward and eastward drift of a high-pressure area to the northwestward of the station. *This development undoubtedly prevented any recurving of the tropical storm and tended to prolong the westward movement of the storm area.*

There was a gradual increase in the intensity of the swells produced by the storm until they became the heavy, frequent swells that prevailed during the late afternoon of the 13th and continued during most of the 14th, dashing high above the sea wall, as the great volume of water was hurled back into the Gulf. There was the usual ebb and flow of tide until the afternoon of the 13th, when the tide began to come in steadily, from which time there was a regular and steady increase in the height of the tide until it reached its highest point of 8.8 feet at 7 a. m. of the 14th. The tide was above normal from about 4 p. m. of the 12th, though there were slight fluctuations as the ebb and flow occurred. From the time the highest tide was reached there was a gradual fall in the tide, though during most of the week following the storm the tide was generally considerably above normal.

As the tide began to rise rapidly late on the 13th, the water began to back in from Galveston Bay, covering the streets in the business section of the city. The low places down the island were flooded by the rising tide. By 7 a. m. of the 14th the streets in the city were covered with water to a depth of from 2 to 3 feet or more, that portion of the city lying north of Avenues F and G being under water, while the low portions down the island were from 4 to 5 feet under water.

The office was besieged with anxious inquirers during the entire week beginning the 8th, the office being kept open until midnight on the 8th, 9th, and 10th, and all night on the succeeding nights. The telephone was kept constantly busy, and bulletins were posted on the board at the entrance of the building in which the office is located. The telephone at the residence of the official in charge was also kept busy during much of the period, members of the family giving out official information as to the storm. On Saturday, the 13th, it being impossible to handle all inquiries on the telephone, the manager of the telephone company placed at the disposal of this office several operators who were given the official bulletins and information. With the aid of these operators we were able to supply information much more quickly and satisfactorily, the congestion of the office telephone being thus relieved.

On Friday, the 12th, as a precautionary measure, the railroad officials were advised to move the cars of grain and other perishable freight to places of safety on the mainland, there being about 3,000,000 bushels of grain on the tracks in Galveston. People owning cattle down the island and the business men generally were advised at this time to arrange to get their stock and goods in places of safety by Saturday. This advice was repeated on Saturday and people were informed that while the storm would probably not strike Galveston, it would undoubtedly cause high tides and high winds in this vicinity. People were told on Saturday that the weather map showed that the storm had not yet gone inland and that until it had definitely passed inland it was best to take all possible precautions.

As conditions began to become more threatening on the 13th, large numbers of people left town, trains and interurbans being crowded to capacity. People living in exposed places were advised to come into town until the storm was over. The city authorities cooperated in spreading this information and bringing the people to places of safety. All precautions were taken for safety. On Saturday night all coast territory was advised to take protective measures, use being made of the telephone, telegraph, and radio. Because of the closing of some of the offices, however, it was impossible to reach several

points, but by midnight all points that it was possible to reach had been given this advice.

Owing to the precautions taken, the property damage was slight in this immediate vicinity. Some damage was done outside the sea wall where the East End Fishing Pier, at Sixth and Boulevard, was destroyed by wave action. The concrete approach to the beach at Thirty-fifth and Bouvelard was broken by having the rip rap hurled against it by the water. The United States Engineer Office was able to save the machinery used in building the extension to the sea wall on the flats east of the city, but lost some lumber that they had stored at Fort Point and some forms used in connection with the sea wall. From 3,000 to 4,000 bales of cotton, mostly from the Moody Press, floated away as the water rose and had to be salvaged. There was practically no loss of live stock here, as all the cattle had been brought from points down the island to places of safety in town. Some few hogs and some poultry that could not be located and collected were lost. Business men in town lost very little from the storm, as they had practically all taken precautions and had raised their stocks above the level of the water. The causeway connecting Galveston with the mainland suffered no injury, though the sand-filled approach to the causeway was washed, undermining some 1,700 feet of railroad track. This damage was soon repaired, and railroad and interurban traffic was resumed at 5 p. m. on September 15.

Two men lost their lives in the storm in this immediate vicinity, one a fisherman who was camping on the low flats east of the city and the other another man, probably a fisherman, who lost his life on the shore of the mainland opposite the middle portion of Galveston Island. Both men were apparently overtaken by the rising tide and drowned. So far as is known, there were no other lives lost in this storm-warning district from the hurricane.

From reports received the height of the tide accompanying the storm ranged in this district from about 4 feet at Orange, Tex., to approximately 13 feet at Port O'Connor, Tex. With this tide and the high wind accompanying it, some damage resulted at many points, especially along the water front. At Seabrook, Tex., there were a few buildings, mostly light structures, destroyed. At Texas City, Tex., there was little damage of consequence done. At points to the south of Galveston, however, there was more damage done. At Velasco and Freeport, Tex., there was some damage done, but I have been unable to get any report of the damage in detail. At Matagorda, Palacios, and Port Lavaca, Tex., there was considerable damage to wharves, fish houses, and small boats. Similar damage resulted at Port O'Connor, Tex., where several small houses were swept away. At Palacios the bathhouses and several small pavilions at the B. Y. P. U. encampment grounds were destroyed. The following estimate of property loss and damage in this district is given:

Seabrook, Tex	$2,000
Galveston, Tex	60,000
Velasco and Freeport	10,000
Matagorda	30,000
Palacios	10,000
Port Lavaca	100,000
Port O'Connor and Seadrift	40,000
Total	252,000

To the north and east of Seabrook there was slight damage done by the storm, though the Gulf & Interstate Railroad suffered a series of washouts in the vicinity of Camden. It is estimated that the damage to the railroad will approximate $20,000. This, added to the total given above, increases the total damage in this district to $272,000. All these estimates of the amount of damage are only approximate and they may be subject to change.—*A. H. Scott.*

THE HURRICANE AT CORPUS CHRISTI.

All day of September 13, 1919, there were upper clouds in the sky. They were mostly cirrus and alto-cumulus, but with occasional patches of cirro-cumulus and a few banks of alto-stratus. The cloudiness varied from almost no clouds at all at times to eight-tenths cloudy at other times. These clouds were moving from almost due east all the time. In the evening, the alto-cumulus clouds covered the sky and did not disappear until the approach of the heavy nimbus clouds.

In spite of a steady north wind, the weather was very oppressive all day. The water in the bay was rather high and rising somewhat in the evening, which appeared unusual, as we ordinarily have low water with north winds.

During the late afternoon of that day, some persons on the roof of the six-story hotel at Rockport, Tex., observed a dark line along the eastern horizon. They watched the dark line till nightfall, during which time it rose slowly and appeared as a dark gray band along the eastern portion of the sky. They report no fringing cirrus or cirro-stratus clouds.

A party of workmen on St. Josephs Island report that between 10 a. m. and noon of the 13th the sea began to rise and became very choppy. By 2 p. m. the tide had risen so much that they left the island and went to Rockport. An hour or two later similar conditions were noted at Port Aransas and by a little after sunset the tide had reached 5 feet above mean sea level.

At all places along the coast unusual swarms of flies were noted on the 13th, and that these flies were very troublesome and persistant in sticking persons and animals has been frequently mentioned.—*C. E. Heckathorn.*

The following extracts from the Houston Post, September 19, 1919, give a picture of the experiences of the people and other effects of the storm:

Stretching along the beach for 23 blocks homes were crushed and hurled away or wrecked by the tidal wave, which reached a depth of 15 feet in some places. Over much of the beach section [on the point north of Weather Bureau office, see fig. 1] not an indication of former homes now remains, except here and there a bathtub or part of a brick chimney.

From Star Street, where the business section on the beach terminated, to Dan Reid Street every one of the 900 beach homes has been destroyed, most of them beyond trace, while here and there a mourning palm tree hanging low, its oil-begrimed leaves marking the spot of some former show place. In this section the bay line has changed, the water having established a new line varying from 50 to 200 feet inland from the former position. This change extends from the business district to the end of the north beach and out as far as Carroll Street, a distance of eight blocks.

* * * In the downtown district utter demolition of some of the city's most important industrial and public plants marked an area extending for six blocks along the water front and more than a block in width, while beyond that block, extending back toward the bluff section, every commercial establishment's first floor was wrecked, and in some cases the entire building rendered useless, over a corresponding area two blocks wide.

The tremendous property damage is becoming daily more apparent and prominent business men and other trained observers predicted to-night [Sept. 18] that $20,000,000 would be a conservative estimate of the monetary loss in Corpus Christi.

284 bodies, almost entirely those of Corpus Christi victims, have been found in the following places and buried:

Corpus Christi	57
White Point	121
Rosita and Portland	80
Oden and Sinton	11
Port Aransas	5
Aransas Pass	2
Rockport	8

* * * Details of conditions at Port Aransas and other parts of the islands between Corpus Christi Bay and the Gulf were ascertained Thursday by Regular Army aviators who flew over that territory. Their survey was confirmed by Capt. Max Luther, collector of customs at Port Aransas. The docks and buildings in Port Aransas have been wiped out with the exception of a school building, and three vessels—the steamer *Median* and two large tankers, the *Juanita* and *Susquehannah*—were reported "high and dry" upon the island. The large oil tanks there also were destroyed. * * * The five who lost their lives [at Port Aransas] were drowned while attempting to leave the island in a lifeboat.

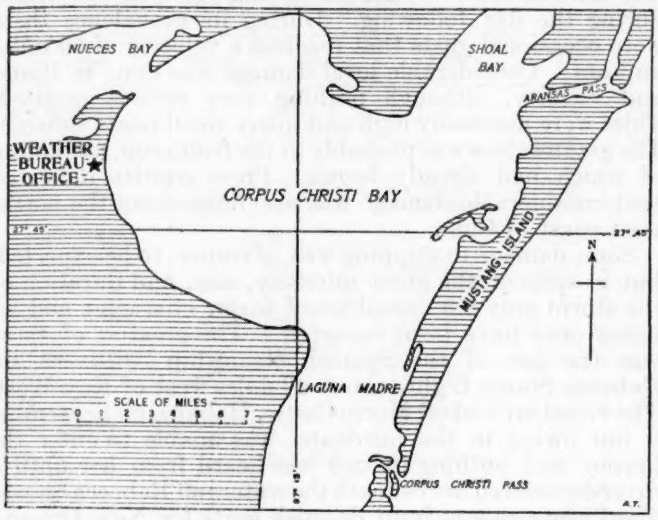


FIG. 1.

* * * As the water came in, an old captain, who has charge of some Government boat there [at Port Aransas], steered his ship in over the island toward the sand ridges where the people were perched hunting safety. As the water rose he went still farther in, stowing the folks away on his ship, sailing over the island from one sand hill to another.

* * * Of the many tales of personal heroism none that has come to light exceeds that of Esther Fuller, 17 years of age.

Esther and her 9-year-old brother Ted, were swept into the tidal wave when their home was carried away during the height of the storm Sunday afternoon. The boy was hit by a piece of débris while struggling in the water and rendered unconscious.

The girl grabbed him just as he started down and began her battle with the wind and waters. Making use of every bit of driftwood and wreckage that came her way she struggled on, sometimes clinging to a housetop, and at others only [to] a board. At other times she was forced to swim until almost exhausted before another piece of wreckage came within her reach.

For 5 miles she fought the hurricane and the waves. She and her brother were finally washed ashore on the opposite side of the bay [near Sinton] where they were found [alive] early Monday morning.

ANAHUAC, MEXICO, *September 18*.—The Gulf storm caused a 6-foot tide here, but Anahuac is situated on a 25-foot bank of Trinity Bay, hence no damage was done. The wind reached a velocity of perhaps 30 miles. The bulkhead across Trinity Bay was damaged, the fill at one end near the lock being washed out.

PATH OF THE HURRICANE.

The path of the hurricane, as nearly as it could be computed, is shown on Chart II. It was compiled from all available information, much of which was received some time after the storm. It will be seen from the chart that the first indication of the disturbance can be noted on the evening of September 6, probably about 130 miles west-northwest of Turks Island, West Indies, but it was not until the receipt of a belated report on September 8 that a severe storm could be located south of and near the Andros Islands. After the morning of the 10th, at which time the storm center was apparently very near Dry Tortugas, Fla., its path could only be approximated. It happened, however, that a report received by mail from the steamship *Lake Deval* nearly two weeks after the storm located the center with a fair degree of definiteness on the morning of the 12th of September, and its position nearly coincided with the estimated position given out on that morning. Attention is invited to the fact that the storm center was about eight days in traveling from the eastern Bahamas to the interior of extreme southern Texas, a remarkably slow, and in this respect a probably hitherto unprecedented, rate of movement.

This storm was only the second September storm of this character of any consequence that reached the south Texas coast during the last 45 years, the other having occurred in 1910. The storm of 1919 was by far the more violent of the two, and was probably the greatest of all Gulf storms. The entire absence of radio reports from vessels in the Gulf was the first instance of the kind since the establishment of the vessel-reporting service some years ago, and, while this fact might be considered as a tribute to the efficiency of the Weather Bureau Service, it was nevertheless a source of considerable embarrassment to the forecaster, as he was obliged to base his conclusions entirely upon observations far removed from the storm center, with consequent probability of a certain amount of error, which probability was reflected in the widespread character of the warnings, which would have been localized much more definitely if some definite radio information had been available. As one press report had it, "The Weather Bureau suffered from its own efficiency." The adoption of measures that will effectively prevent a repetition of this occurrence presents a question that must receive early consideration.

BAROMETER READINGS DURING THE STORM.

The barometer readings near and at the center of the storm were almost unprecedentedly low, although at Key West, which was only about 30 miles north of the center as it passed, the lowest sea-level reading was only 28.83 inches, whereas during the hurricanes of 1909 and 1910 the lowest readings at that place were 28.52 and 28.47 inches respectively. At the Sand Key station, about 8 miles southwest of Key West, and consequently about an equivalent distance nearer the storm center, the lowest barometer reading was 28.35 inches. Even if no other evidence were available, the difference of 0.48 inch over the 8 miles between Key West and Sand Key would indicate that at the center of the storm the pressure was very much lower, and later readings obtained by mail from other sources, including vessels in the Gulf of Mexico, afforded positive confirmation of the fact. In his report the official in charge at Key West stated that the center of the storm passed directly over Dry Tortugas, 65 miles west of Key West, with a reported barometer reading of 27.51 inches, while at Rebecca Shoals Light, about 40 miles west of Key West, the lowest reading was 27.66 inches. The barometers at these two places were later compared with another instrument whose correction was known, and the observed readings corrected accordingly. The steamship *Winona* went ashore at 10 a. m., September 10, on a reef on the northeast portion of the Tortugas group, near Pulaski Shoals. She had been in that vicinity for at least 18 hours, and

from 12 noon until 4 p. m. of the 9th the barometer fell from 29.40 to 27.70 inches, a fall of 1.70 inches in four hours. From 4 p. m. to midnight there was a further fall to 27.45 inches, or a total fall of 1.95 inches in 12 hours. These three readings, differing but 0.21 inch within a very limited area, make it safe to assume that they were substantially correct. A later report from the tank steamer, *Fred W. Weller*, showed a barometer reading of 27.36 inches in the vicinity of Dry Tortugas on September 9. It is understood that the barometer carries a Weather Bureau correction. The only other readings from the vicinity of the storm center also came by mail, and were as follows: Steamship *Lake Deval*, at 9 a. m., September 12, in latitude 26° 10′ north, longitude 87° 50′ west (approximate), 27.89 inches; steamship *Lake Grandon*, at 4 p. m., September 12 (exact position unknown, but doubtless somewhere near latitude 27° north and longitude 89° west), 27.99 inches; steamship *Tegucigalpa*, at 5 p. m., September 12, latitude 26°:58′ north, longitude 88°:30′ west, 27.81 inches; another report received by mail on October 29 from the captain of the steamship *Berwyn* stated that his vessel passed through the storm center at midnight of September 12, at latitude 26°:30′ north, longitude 90°:30′ west, with a barometer reading of 27.50 inches; steamship *F. R. Kellogg*, at 9 a. m., September 14, latitude 27° north, longitude 95° west (approximate), 28.07 inches. No other readings were obtained from the Gulf of Mexico, and the next available ones were from the Weather Bureau stations on the Gulf coast. The lowest readings were 28.65 inches at Corpus Christi, Tex., a short distance north of the storm center, at 3 p. m., September 14; 29.13 inches at Brownsville, Tex., at 1 p. m., September 14, and 29.65 inches at Galveston, Tex., at 12.30 a. m., September 14. The lowest barometer reading reported was that of the steamship *Fred W. Weller*, 27.36 inches.

At Habana, Cuba, on October 11, 1846, a barometer reading of 27.06 inches was reported,[1] and there is a record of 26.85 inches at Morne Rouge, Island of Martinique, on August 18 or 19, 1891.[2] The character and accuracy of the barometer from which the latter reading was made is not known, but, assuming that the reading was accurate, it is doubtless the lowest reading of record for the Western Hemisphere.

Wilhelm Krebs, in the article before quoted, makes mention as follows of two still lower barometer readings, both in the Eastern Hemisphere: At Vohemare, on the coastal lowland of northeastern Madagascar, on February 3, 1899, 24.76 inches, and on board the steamship *Arethusa*, latitude 13° 35′ north, longitude 134° 30′ east, on December 16, 1900, 26.16 inches.

STORM EFFECTS.

Except on the south Texas coast, the land damage was slight. The full force of the storm was experienced between Aransas Bay and the mouth of the Rio Grande, where the high tides resulted in a toll of 183 dead and 174 missing. It is probable that some of the missing were also listed among the unidentified dead, and, if so, the total casualties will be somewhat reduced.

Along the Mississippi coast the highest tides of the season were experienced, but the winds were not unusually high, and there was little or no damage reported. At Pensacola, Fla., the highest wind velocity reached was 40 miles an hour from the east during the afternoon of September 13. At Tampa, Fla., the maximum wind velocity reported was 34 miles an hour from the northeast during the late afternoon of September 10, and on the following day the tide reached a crest of 5.55 feet above low-water mark, 2 feet higher than ever before recorded in the annals of the United States Engineers. The tide did some little damage along that section of the coast, but none of consequence. No high winds were reported at Fort Myers, Fla., the only Weather Bureau station between Tampa and Key West.

The storm history at Key West and Sand Key will be found in the reports of the officials at those stations. At Miami, Fla., the highest sustained wind velocity reported was 46 miles an hour from the east during the late afternoon of September 9, and the gale continued during the day following. During its prevalence there were occasional gusts that reached a velocity of 60 miles an hour. Considerable local damage was done in Miami and vicinity, although nothing very serious resulted. Tides were unusually high and many small boats suffered. The greatest loss was probably in the fruit crop, marketing of which had already begun. Press reports indicated that considerable damage was also done along the northwest coast of Cuba.

Some damage to shipping was, of course, to be expected, but in spite of the great intensity, size, and duration of the storm only ten casualties of major character and 25 minor ones have been reported. The greatest of these was the loss of the Spanish steamship *Valbanera*, off Rebecca Shoals Light, about 40 miles west of Key West. The vessel arrived off Morro Castle, Habana, on September 9, but owing to the hurricane, was unable to enter the harbor, and nothing further was heard from her until a diver discovered her beneath the waters off Rebecca Shoals. The *Valbanera* was from Spanish ports for New Orleans, via Habana, and her 400 passengers and crew of 88 must have perished.

The other wreck was that of the Ward Line steamship *Corydon*, on the morning of September 9, in approximately latitude 24° north, and longitude 79° west. Of the crew of 37 men, 27, including the captain, went down with the boat. Ten men escaped in a lifeboat, and nine of them were picked up two days later at Cape Florida, a few miles south of Miami. The tenth man, who became insane while in the boat, was washed overboard. The lowest barometer reported by the *Corydon*, through Third Officer B. L. Mallows, who was one of those rescued, was 28.34 inches at 11 p. m., September 8.

As regards the losses of or damage to vessels (Tables 1 and 2) it will be noted that none had left port after storm or hurricane warnings had been issued, i. e., after the 8th from Florida ports or after the 10th from other Gulf ports. Of those which had sailed earlier it is not stated how many did or could have received warnings by radio.

An aftermath of the storm was a tornado that swept through the business district of Goulds, Fla., a small town south of Miami, about 1 p. m., September 10. The center of the tropical storm at that time was probably about due west of Goulds, at some considerable distance. (See account on p. 639.)

[1] Marcus T. Melero, Diario de la Marina, Oct. 9, 1873.
[2] Krebs, MONTHLY WEATHER REVIEW, March, 1911, 39: 471.

TABLE 1.—*Vessels reported lost or missing (extracted from New York Maritime Register, September to October, 1919).*

Vessel.	Nation.	Reg.	From—	Date.	Last seen.	Date.	Bound for—	Remarks.
Bayronto	Brit.	S. S.	Galveston	Sept. 6			Marseille	Foundered Sept. 13 in latitude 26° 45′ N., longitude 83° W.; 19 of crew rescued by S. S. Calno.
Copperfield	Amer.	Schr.	Mobile	Aug. 25				Abandoned near Rebecca Shoal Sept. 11; crew saved. Subsequently towed to Tampa.
Corydon	Amer.	S. S.	Antilla	Sept. 6				Foundered in Bahama Channel, Sept. 9, with loss of 27 lives. One boat of survivors.
Hugh de Payens	Amer.	Schr.	Mobile				Ponce	Wrecked in Florida Straits. Crew rescued by S. S. Olinda.
Lake Conway	Amer.	S. S.	Philadelphia	Sept. 2			Habana	Due at Habana Sept. 10. Crew of 31.
Larimer	Amer.	Tank S. S.	Port Arthur	Sept. 5	Off Key West	Sept. 8	Baltimore	Reported "missing" in N. Y. Maritime Register of Nov. 5.
Maud H. Dudley	Amer.	Schr.	Pensacola	Aug. 31			Habana	Abandoned 40 miles off Habana Sept. 13. Crew rescued by S. S. Lake Ielan. Picked up 17th by fishermen off Knights Key, dismantled and full of water.
Munisla	Amer.	S. S.	Mobile	Sept. 8			Habana and Pensacola.	Lost in Gulf about Sept. 10.
Preston	Norweg.	S. S.	New Orleans	Sept. 9	Anchored below New Orleans.	Sept. 10	St. Jago	
Valbanera	Span.	S. S.	Barcelona		Off Habana harbor.	Sept. 9	Habana	Sank near Half Moon Key on Sept. 11 (?). No survivors of large crew and passenger list.

Two schooners reported to have gone down on Cat Island, Bahamas, with all on board.

TABLE 2.—*Vessels damaged by the hurricane (extracted from New York Maritime Register, September to October, 1919).*

Vessel.	Nation.	Reg.	From—	Date.	Bound for—	Remarks.
A. C. Bedford		Tank S. S.	Port Lobos	Sept. 5	Baltimore	Considerably damaged. Lost 8 boats, sprung a leak and lost about 5,000 tons of oil.
Calno		S. S.	Mobile	do	Amsterdam	Put into Charleston Sept. 16, with deck and engine room damaged and deck load lumber shifted. Rescued 19 members of crew S. S. Bayronto. Returned second time to Charleston to repair machinery.
Comal		S. S.	Galveston	Sept. 6		Aground at Key West. While aground was rammed by U. S. S. Wheeling.
Delmira	Brit.	Tank S. S.	New Orleans	Sept. 8	Antilla	Sept. 19, put back into New Orleans for repairs after damage in severe gale [hurricane].
Edward Sewall		Ship	Port Arthur	Sept. 6	La Plata	Broke from tow and sustained considerable damage. Returned to Port Arthur on 13th.
Elizabeth Bandi		Schr.	Gulfport	July 13	St. Thomas	Arrived St. Thomas Oct. 23. Reported captain drowned during heavy weather.
El Mar		S. S.	New Orleans	Sept. 9	New York	Put into Key West Sept. 12 to restore cargo.
Flavel		S. S.	Galveston	Sept. 6	Helsingfors	Put into Key West damaged. Proceeded Sept. 14 to Jacksonville for repairs.
Fred W. Weller		Tank S. S.	Tuxpam			Arrived Key West Sept. 12, damaged during hurricane.
Gartyma	Greek	S. S.	New York	Aug. 20	Sagua	Put into Jacksonville Sept. 13 for repairs.
Gulflight		Tank S. S.	Port Arthur	Sept. 9	Jacksonville	Arrived at Jacksonville with all stores destroyed and one tank leaking.
Hillsboro County		S. S.	Habana	Sept. 8	Cardenas	Driven ashore on north Cuban coast Sept. 9. Crew saved.
Hornet		S. S.	Bluefields		Pensacola	Sustained slight damage and loss of part of deck load.
Lake Duane		S. S.	Mobile	Sept. 5	Habana	Put into Key West, Sept. 12, damaged, but proceeded.
Lake Grandon		S. S.	New Orleans	Sept. 10	Hull	Returned to port in distress.
Lake Winona		S. S.	do	Sept. 7	Porto Rico	Went ashore on Dry Tortugas during hurricane, but subsequently towed into Key West. Bottom reported badly damaged.
Ligonier		Tank S. S.	Port Arthur	Sept. 6	Savannah	Machinery disabled, lifeboats, ventilators, and wireless blown away. Lost tow barge Monongahela.
Median	Brit.	S. S.	Liverpool	Aug. 20	Port Aransas	Lifted on apron of wharf at Port Aransas during hurricane. Later floated undamaged.
Monongahela		Oil barge	Port Arthur	Sept. 6	New York	In tow S. S. Ligonier. Broke tow but later picked up. No damage; crew safe.
Palafox		Aux. schr.	Santa Cruz, Cuba	Aug. 28	Tampa	Partially disabled and put into Gulfport on Sept. 17 for repairs.
Randolph S. Warner		S. S.	Philadelphia	Sept. 5	Houston	Went aground near Hillsboro Lighthouse; subsequently refloated.
Tonawanda	Brit.	Tank S. S.	Barry	Aug. 9	Tampico	Broke away from dock and went ashore in Key West Harbor, Sept. 9.
U. V. Drew	Brit.	Schr.	Tampa	Sept. 8	Sagua	Arrived Key West on Sept. 9 in sinking condition.
War Jandoli	Brit.	Tank S. S.	Port Arthur	Sept. 4	Hull	Went aground at Key West night of Sept. 8. Got off next night and went ashore on Crawford Bar.
War Mogul	Brit.	Tank S. S.	do	Sept. 6	Lough Swilly	Put into Habana, Sept. 11, with cargo leaking into double bottom.

WARNINGS FROM OTHER DISTRICTS.

New Orleans, La., Forecast District.—The only warnings issued were in connection with the tropical disturbance of the 6th to 14th. Storm warnings were not needed at other times.

Chicago, Ill., Forecast District.—The month was warmer and, in the eastern and central portions, much wetter than usual. Frequent storms passed across the central portion of the district during the second half of the month.

The frost warnings issued were distinctly local and confined to the last week in the month, with special warnings for the cranberry marshes of Wisconsin, which were issued from time to time after the 10th. The frost warnings were, for the most part, verified.

Special fire-weather forecasts were issued for Montana up to September 17, being discontinued on that date at the request of the district forester at Missoula in a telegram, as follows:

> On account lateness of season and present weather conditions unfavorable to fire, unnecessary for you to continue daily telegraphic predictions. Accept appreciation your valued cooperation.

Special forecasts were issued for Topeka, Kans., for the free State fair the week of September 7 to 13, inclusive, and a letter from the official in charge of the Topeka station, dated September 15, makes acknowledgment of the service rendered:

> I wish to thank you for the special forecasts sent us last week for the benefit of the free State fair, held at this place. Each of these forecasts was verified to a nicety and they played a large part in assuring the succes of the fair, which was attended by the greatest crowds that have ever visited Topeka or probably any other Kansas city in the space of six days' time.
>
> These forecasts were given wide circulation by being printed in a prominent place on the front pages of both afternoon and morning newspapers, which go to all parts of the State, and their value was appreciated, as shown by the inclosed editorial clipped from the Topeka Daily Capital and the two inclosed front pages of the Topeka State Journal, which are forwarded instead of clippings to show how prominent a place was given the forecasts and also the article expressing appreciation of them.

Special forecasts were also issued for the implement show and district fair held in Peoria, Ill., the last week in September. A letter, dated October 3, from the official in charge of that station makes reference to the special forecasts, as follows:

> In closing up September business, I desire to again express the appreciation of this station and community for the long range forecasts sent in connection with the recent implement show and district fair. They were of material service to the interests concerned.

At the request of the Chief of Bureau, special forecasts covering the itinerary of President Wilson in the Chicago district were wired to Secretary Tumulty. Under date of September 7, Mr. Tumulty wired the Chicago station, as follows:

"I thank you very warmly for your several telegrams."—*H. J. Cox.*

Denver, Colo., Forecast District.—September was free from the severe temperature conditions that occasionally bring the crop season to an abrupt close about the middle of the month. No killing frosts occurred in agricultural districts. Warnings of light frost were issued on the 21st, 22d, and 23d for parts of the eastern Rocky Mountain slope, and on the 27th for freezing temperature in northeastern Colorado. Practically no damage occurred.—*Frederick H. Brandenburg.*

San Francisco, Calif., Forecast District.—During the first decade of September unsettled and showery weather prevailed in the northern portion of this district breaking the long drought and extinguishing, or permitting to be brought under control, many large and serious forest fires which had been raging in that section. In the southern portion of the district, except for showers in California from the San Francisco Bay section north on the 7th and 8th, fair and seasonable weather prevailed until near the end of the month, when rain fell generally in California and Nevada, breaking the drought and putting out large and damaging forest fires in those States. The rainfall was considerably above the normal in western Oregon and southern California.

The temperature for the month was nearly normal throughout the entire district.

Fire-weather warnings were issued in Washington, Oregon, and Idaho on the 10th, but were not verified, as rain fell the following day in those States.

Rain warnings were issued in northern California on the 7th and 8th, and in the entire State from the 27th to the 30th, and were verified.

Southwest storm warnings were ordered on the morning of the 30th, from the Columbia River north, on the approach of the first north Pacific storm of the season and were verified.

The following commendations were received during the month:

STATE OF WASHINGTON,
DEPARTMENT OF FORESTRY,
Olympia, Wash., September 11, 1919.

I take this opportunity of congratulating you upon the accuracy of the many previous fire-weather warnings you have furnished this Department this season. I consider this service invaluable in the successful protection of our forests and hope your service may be so extended next season that each county and district warden will receive telegraphic forecasts.

F. E. PAPE,
State Forester.

LOCAL OFFICE, WEATHER BUREAU,
Sacramento, Calif., September 13, 1919.

The rain forecast received Sunday morning (Sept. 7) from the district forecaster was repeated to all prune-drying districts in this section, at the expense of the producers, who themselves disseminated the information, and it is quite gratifying to state that few were caught unawares.

The commissioner of horticulture of the State of California stated: "The service in connection with the last rain was unexcelled, and again exhibited the value of the Weather Bureau."

—*G. H. Willson.*

RIVERS AND FLOODS, SEPTEMBER, 1919.

By ALFRED J. HENRY, Meteorologist in Charge.

[Dated: Weather Bureau, Washington, Oct. 25, 1919.]

The severe tropical cyclone that crossed the Gulf of Mexico during the first decade of the month passed westward over the lower Rio Grande Valley and evidently dissipated in heavy rains over that valley (see fig. 1, p. —). As a result the river for at least 100 miles from its mouth overflowed its banks and formed a stream said to have been 40 to 50 miles wide. Much damage was done on both sides of the river but there was very little loss of life due, in part at least, to ample warning of the coming of the floods.

The influence of this storm extended to the northwest as far as New Mexico, where heavy rains on the 15th to the 17th caused freshet stages in the Pecos River (see fig. 1, p. 640).

Closely following the rains in New Mexico very heavy downpours occurred locally over the valley of the Solomon River of Kansas on the 17th and 18th. These heavy rains caused sharp rise in that river to a crest of 33.6 feet at Beloit—15 feet above flood-stage on the 20th. Fortunately the crops throughout the valley were mostly gathered, thus greatly reducing the loss.

No estimates are available at this time as to the loss in the lower Rio Grande. The total damage due to the Solomon River flood is estimated at $416,000, more than 50 per cent of which was to crops. Railroads through the flooded district suffered a loss of $57,500 to bridges, roadbed, etc.

The following additional information respecting the Rio Grande flood has been received:

The flood of the Rio Grande was by far the most disastrous flood during the month and was more severe than any previous flood of that stream of which this office has record. There were in reality two floods of the Rio Grande, which were distinct in the upper portions of the stream, but formed one continuous flood in the lower portions.

At Eagle Pass the river was at flood stage from September 16 to 18, and from September 22 to 25. The crest of the former rise passed Eagle Pass at 11.40 a. m. September 17, with stage 38.5 feet; and that of the latter rise at 1 p. m. September 23, with stage 32.6 feet.

At Laredo the river was flooded September 18 to 20, and September 24 to 26. The highest stage recorded during the former rise was 33 feet at 7 a. m. September 19; and during the latter rise, 30 feet at 6 a. m. September 25.

At Rio Grande City the stream was flooded continuously from September 16 to 29, but there were fluctuations sufficiently large to make a distinction between the two rises. The highest stage recorded was 26.2 feet on September 26.

At Mission the stream was flooded from September 21 to 30, and the highest stage recorded was 27.6 feet at 6 p. m. September 27. No river stations are maintained below Mission by this service; but it was reported that the crest of the flood passed Brownsville at 10 a. m. October 3.

The flood had its inception in the heavy rains attending and following the tropical storm that moved northwestward over the Rio Grande Valley September 14 to 16. The rises at Eagle Pass and Laredo were remarkably sudden. At Eagle Pass the rise during the 24 hours ending at 7 a. m. September 17 amounted to 27.2 feet, and at Laredo during a similar period, ending 7 a. m. September 18, the rise was 18 feet.

Advisory warnings of the second rise were issued to all points along the Rio Grande. Much water appeared to be coming from the San Juan just above Rio Grande City, thus aggravating the second rise; and on September 26 points below Rio Grande City were advised that the secondary flood appeared to be worse than the preliminary.—*B. Bunnemeyer.*

The usual tables follow.

TABLE I.—*Flood stages in the West Gulf Drainage during month of Sept., 1919.*

River and station.	Flood stage.	Above flood stages—dates. From—	To—	Crest. Stage.	Date.
	Feet.			*Feet.*	
Colorado:					
Austin, Tex	18	25	25	19.5	24–25
Columbus, Tex	28	25	28	32.8	27
Guadalupe:					
Gonzales, Tex	22	19	21	24.0	20
Do	22	25	28	27.1	26
Victoria, Tex	16	21	24	20.2	23
Do	16	27	(1)	22.0	30
Rio Grande:					
Eagle Pass, Tex	16	17	18	38.5	17
Do	16	22	24	32.6	23
Laredo, Tex	27	18	19	33.0	19
Do	27	24	25	30.6	25
Rio Grande City, Tex	15	16	28	26.2	26
Mission, Tex	24	21	30	27.6	27

[1] Continued into October.

TABLE II.—*Flood stages in the Mississippi Drainage during month of Sept., 1919.*

River and station.	Flood stage.	Above flood stages—dates. From—	To—	Crest. Stage.	Date.
	Feet.			*Feet.*	
Solomon:					
Beloit, Kans	18	20	23	33.6	20
Republican:					
Clyde, Kans	17	....	....	17.4	20

RIVER GAGINGS ON TANANA RIVER AT NENANA, ALASKA.

SUMMARIZED BY ALFRED J. HENRY, METEOROLOGIST.

The Alaska Engineering Commission (Government Railroad Engineers) has established a river gage at Nenana, Alaska, about half a mile above the confluence of the Nenana River and has been making daily gagings since June, 1916, except when the river was frozen. The elevation of the zero of the gage has been fixed by Mr. Frederick D. Browne, engineer in charge of the Nenana district, at 335 feet above mean lower low water at Portage Bay in Prince William Sound. The gage graduations extend from −1 to 15 feet. Through the courtesy of Mr. Browne the Weather Bureau has been furnished with a copy of the daily gagings for the seasons 1916, 1917, 1918 and up to August of 1919. These have been summarized and the means and extremes appear in the table below.

The Tanana River, it may be remembered, flows from lower to higher latitudes and consequently the ice breaks up first on the headwaters. The river freezes over about the last week in October and water appears on the ice in spring at Nenana in the last half of April, the break-up coming a little later. The total range from extreme low to extreme high water during the period of observations was 18.1 feet and both highest and lowest water were due to ice conditions. The lowest water was −0.6 on November 1, 1916, and the river froze on that date. There does not appear to be a pronounced snow flood in the spring as the ice breaks up. The river is highest on the average of 4 seasons in July and gradually declines until freezing sets in in the autumn. The daily variations are small, rarely as much as 2 feet. The absence of heavy summer rains and a small run-off from such precipitation as occurs during the open season seems to indicate that the flood menace, if any, must be confined to the breaking up of the ice in spring.

Monthly means and extremes of river gagings on Tanana River, at Nenana, Alaska.[1]

[Monthly means = feet and tenths.]

Year.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1916	....	9.3	9.4	7.9	5.8	4.3	....
1917	5.6	7.5	11.3	9.3	6.3	2.1	....
1918	9.9	11.9	10.6	9.3	6.5	3.1	....
1919	5.8	7.9	10.6	9.5	....	....	....
Means	7.1	9.1	10.5	9.0	6.2	3.2	....
HIGHEST.							
1916	....	10.9	10.6	10.0	7.3	8.5	....
1917	9.3	9.2	14.1	11.5	10.9	3.2	....
1918	17.5	16.0	11.7	11.1	8.4	4.4	....
1919	7.8	10.5	12.0	11.1	....	....	....
LOWEST.							
1916	....	6.9	8.3	5.6	3.7	0.1	−0.6
1917	2.6	5.7	8.8	7.0	3.4	0.2	....
1918	3.7	9.9	9.3	7.0	4.2	−0.4	....
1919	....	....	....	....	....	....	....

[1] Zero of gage 335 feet above mean lower low water at Portage Bay, Prince William Sound.

MEAN LAKE LEVELS DURING SEPTEMBER, 1919.

By UNITED STATES LAKE SURVEY.

[Dated: Detroit, Mich., Oct. 6, 1919.]

The following data are reported in the "Notice to Mariners" of the above date:

Data.	Lakes.[1] Superior.	Michigan and Huron.	Erie.	Ontario.
	Feet.	*Feet.*	*Feet.*	*Feet.*
Mean level during Sept., 1919:				
Above mean sea level at New York	602.55	580.81	572.75	246.86
Above and below—				
Mean stage of Aug., 1919	−0.04	−0.33	−0.39	−0.4
Mean stage of Sept., 1918	+0.04	+0.31	+0.28	+0.66
Average stage for Sept., last 10 years	−0.08	+0.14	+0.38	+0.73
Highest recorded September stage	−1.53	−2.62	−1.19	−0.75
Lowest recorded September stage	+1.06	+1.15	+1.47	+2.86
Average relation of the September level to—				
August level	....	−0.2	−0.2	−0.4
October level	....	+0.2	+0.3	+0.4

[1] Lake St. Clair's level: In September, 575.61 feet.

EFFECT OF WEATHER ON CROPS, SEPTEMBER, 1919.

By J. WARREN SMITH, Meteorologist in Charge.

Farm work.—The weather during September was favorable for farm work generally, especially for thrashing small grain and for general harvesting, except that during the first half the soil was too hard and dry for fall plowing and the preparation of seed beds for winter grains in some western and in many central districts and also in the Southeast, while in the Southwest work was considerably retarded by wet ground. Soon after the middle of the month, however, good rains fell in most of the central districts where dry weather had persisted, putting the soil in good condition, and thereafter this work made rapid advance.

Small grains.—Harvesting of the grain crops in the late districts and thrashing in all sections where not previously completed made good progress during the month under favorable weather conditions, except for a few relatively unimportant interruptions by rain, principally in the far Northwest and in some north-central border States. Spring wheat continued to show disappointing yields, although turning out somewhat better than was expected in some central sections of the spring-wheat belt. Buckwheat harvest was completed the latter part of the month in the western Lake region, and a good crop of this grain had been mostly harvested at the close of the month in the Appalachian Mountain districts and in the Northeast. Grain sorghums stood the drought well in the southern Great Plains, and harvest was nearing completion at the close of the month. Flax in the upper Great Plains matured and was harvested during the month without material damage by frost. The weather was mostly favorable for rice, although considerable damage to this crop resulted from the high wind and tide along the west Gulf coast about the middle of the month; an excellent crop was being harvested in California.

The seeding of winter grains in much of the principal winter-wheat belt during the first half of September was delayed by continued dry weather and very little wheat was sown before the middle of the month. During the latter half of the month, however, rains put the soil in good condition in most central districts and seeding made rapid progress; but the absence of material rainfall in nearly all of the far Northwest continued seriously to delay seeding in that area, and the early sown wheat in some districts failed to germinate properly, particularly in Montana. The seeding of winter rye progressed satisfactorily, except where prevented by dry soil, as indicated above; the early sown came up to a good stand in most sections.

Corn.—Corn matured rapidly during the first half of the month, too rapidly in portions of the Great Plains, and most of it was out of danger of frost in the extreme northern districts by the close of the first decade. The continued dry weather during the first part of the month in some places in the Ohio and lower Missouri Valleys and in much of the central Great Plains caused corn to deteriorate in these districts, but the weather was favorable in much of the Ohio Valley and in the upper Mississippi Valley, where the crop continued in good condition. Little damage resulted to corn by frost, and at the close of the month the crop was out of danger in all central and northern districts, and cutting and shocking had made good progress under favorable weather conditions.

Cotton.—The rainfall during the first half of September was light throughout practically the whole of the cotton belt, except that it was heavy in southern Texas toward the middle of the month, when the tropical cyclone visited that section, and high winds and heavy rains did great damage to unpicked cotton. Heavy rainfall continued in much of Texas during the greater part of the week ending September 23 also, but elsewhere very little rain fell during the latter half of the month, and temperatures continued mostly seasonable. Cotton made good progress during the month in Oklahoma, western and northwestern Texas, and fairly satisfactory advance in Tennessee and much of Arkansas. It deteriorated in eastern Texas, however, as a result of wet soil and insect pests, and there was a sharp decline in condition at the end of the month in Louisiana and some deterioration in Mississippi. Progress was fairly good in most of the Carolinas, but poor, on the whole, in Alabama, Georgia, and Florida. The bolls opened rapidly during the month, and picking made satisfactory progress in most sections, except for some delay in Texas on account of rain and labor shortage.

Pastures, truck, and fruit.—There was some improvement in white potatoes in the central Rocky Mountain and Lake regions the first half of the month, but this crop showed unfavorable results from the previous warm, dry weather in many central and western sections of the country. It continued too dry for pastures in the interior and in some eastern districts and in much of the Northwest, but rains benefited ranges materially in the central and southern Rocky Mountain and Plateau regions. Deciduous fruit ripened rapidly in the northern and western States, and citrus fruit did well in California and Florida. The weather was favorable for curing tobacco in New England, but the late crop deteriorated in Virginia and much of Kentucky on account of the drought. The rains the latter part of the month improved pastures in most interior sections of the country, but dry weather continued in the Southeast, where pastures and truck crops were unfavorably affected, while there was too much moisture for truck in the Southwest.

CLIMATOLOGICAL TABLES.*

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, September, 1919.

Section.	Temperature.								Precipitation.					
	Section average.	Departure from the normal.	Monthly extremes.						Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.	Lowest.	Date.			Station.	Amount.	Station.	Amount.
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	75.3	0.0	Evergreen	100	11	Valley Head	44	26	0.77	− 2.72	Eufaula	4.77	11 stations	0.00
Arizona	72.7	− 0.5	Mohawk	112	3	Moccasin	27	23	2.56	+ 1.35	Sycamore R. S.	5.65	Yuma W. B.	0.03
Arkansas	74.6	+ 0.9	Bee Branch	108	10	Gravette	40	12	2.72	− 0.85	Higden	6.30	Warren	0.42
California	67.3	− 1.2	Needles	112	21	Portola	20	5	0.98	+ 0.49	Kennett	5.39	5 stations	0.00
Colorado	59.5	+ 2.9	Lamar	101	5†	3 stations	14	22†	1.94	+ 0.53	Silver Lake	5.07	Garnett	0.11
Florida	79.5	+ 0.2	Marianna	99	18	3 stations	50	29†	4.83	− 2.15	Key West	14.26	Mount Pleasant	0.43
Georgia	75.0	+ 0.2	3 stations	99	11†	Clayton	43	29†	1.41	− 2.04	Quitman	6.35	3 stations	0.00
Hawaii (August)	75.2	+ 0.5	Mahukona	94	16	3 stations	54	2†	4.52	− 1.90	Eke Maui	23.50	4 stations	0.00
Idaho	58.3	+ 1.6	Glenns Ferry	102	11	Irwin	15	22	1.13	+ 0.10	Grand View R. S.	3.93	Deer Flat	0.02
Illinois	69.9	+ 2.8	2 stations	102	10	Joliet	33	26	3.57	0.00	Mount Carroll	7.74	Fairfield	0.75
Indiana	69.4	+ 2.4	2 stations	101	9†	Bluffton	33	26	2.41	− 0.62	Marion	4.79	Farmland	0.45
Iowa	67.5	+ 4.1	3 stations	99	7†	Inwood	33	25	5.34	+ 1.98	2 stations	11.82	Forest City	1.49
Kansas	72.5	+ 3.4	Norwich	105	9	Blakeman	29	23	2.64	− 0.28	Burr Oak	9.02	Arkansas City	0.07
Kentucky	71.5	+ 1.5	Earlington	102	10	Taylorsville	40	27	1.69	− 1.07	Franklin	3.65	Earlington	0.56
Louisiana	78.0	+ 0.5	Grand Cane	100	11	Grand Cane	48	3	2.54	− 1.49	Lawrence	7.62	St. Francisville	0.44
Maryland-Delaware	68.1	+ 0.8	Hancock, Md	100	8	Oakland, Md	31	28	2.32	− 0.84	Emmitsburg, Md	3.42	Hancock, Md	0.75
Michigan	61.8	+ 1.9	2 stations	97	8†	Humboldt	21	26	3.16	+ 0.20	Allegau	6.30	Omer	0.80
Minnesota	60.7	+ 2.5	2 stations	94	7†	Angus	23	25	1.82	− 1.10	Worthington	5.24	New London	0.20
Mississippi	76.1	+ 0.2	Columbus	103	11	Corinth	47	24	1.13	− 2.51	Brookhaven	2.83	University	T.
Missouri	71.4	+ 2.7	Caruthersville	104	10	Cassville	38	11†	3.29	− 0.54	Mexico	8.66	Lockwood	0.30
Montana	56.2	+ 1.0	Outlook	100	12	Bowen	3	22	0.93	− 0.65	Browning	4.96	East Anaconda	0.13
Nebraska	67.8	+ 4.1	2 stations	104	9	Gordon	24	25	2.94	+ 0.79	Bruning	10.05	Ericson	0.10
Nevada	61.5	+ 1.1	Logandale	105	3	Potts	20	22	0.66	+ 0.29	San Jacinto	1.97	2 stations	T.
New England	59.4	− 0.1	Bridgeport, Gonn	94	8	Somerset, Vt	21	4	5.02	+ 1.39	Rutland, Mass	8.58	St. Johnsbury, Vt	2.59
New Jersey	65.8	0.0	2 stations	96	8	Culvers Lake	30	27	3.26	− 0.80	Pompton Plains	6.28	Woodbine	1.04
New Mexico	64.6	+ 0.8	Artesia	104	3	2 stations	22	22†	3.57	+ 1.52	Carson Seep R. S.	14.85	Aztec	0.24
New York	61.7	+ 0.7	Roslyn	94	7	Indian Lake	24	27	3.11	− 0.23	Bedford Hills	7.52	Penn Yan	0.61
North Carolina	69.9	0.0	Mount Airy	100	10	Banners Elk	31	29	1.23	− 2.66	Smithfield	5.33	Pinehurst	T.
North Dakota	58.6	+ 2.2	Forman	100	5	Minot	20	25	0.92	− 0.72	Minot	3.18	Forman	0.06
Ohio	66.7	+ 1.1	2 stations	99	9	Paulding	32	27	1.90	− 0.87	Cincinnati	3.79	London	0.83
Oklahoma	75.0	+ 0.8	Mutual	109	10	Kenton	36	23	1.36	− 1.70	Antlers	6.18	Buffalo	T.
Oregon	58.8	0.0	La Grande	99	16	Fremont	14	29	1.70	− 0.01	Headworks	5.57	Union	0.17
Pennsylvania	64.4	+ 0.4	3 stations	96	7†	West Bingham	28	27	2.07	− 1.43	Lykens	4.09	Williamsport	0.46
Porto Rico	78.5	− 0.4	3 stations	96	7†	Toro Negro Dam	59	16	8.73	+ 0.61	Toro Negro Dam	15.17	Isabela	2.96
South Carolina	74.1	+ 0.1	2 stations	99	9†	Landrum	45	29	0.97	− 2.93	Cheraw	4.14	3 stations	0.00
South Dakota	63.8	+ 2.9	6 stations	100	5†	Eureka	25	25	1.37	− 0.42	Tyndall	4.63	Eureka	0.04
Tennessee	72.2	+ 1.0	Copperhill	103	11	Crossville	38	25	1.50	− 1.53	Springville	7.05	2 stations	T.
Texas	76.2	− 0.8	La Pryor	105	9	Romero	39	23	4.88	+ 2.09	Boerne	13.90	Clarksville	0.76
Utah	62.2	+ 2.5	St. George	102	11	3 stations	21	13†	1.88	+ 0.62	Silver Lake	6.11	Hanksville	0.00
Virginia	68.8	+ 0.4	2 stations	98	8†	Burkes Garden	27	29	1.18	− 2.14	Woodstock	2.77	Swansonville	0.20
Washington	58.8	+ 0.5	Trinidad	98	16	2 stations	16	29	1.70	+ 0.06	Cedar Lake	5.25	Maryhill	0.01
West Virginia	66.0	− 0.2	Moorefield	98	6†	Brandywine	31	29	2.11	− 0.81	Rowlesburg	4.37	Sutton	0.12
Wisconsin	61.7	+ 2.3	Racine	97	8	Long Lake	22	26	3.73	+ 0.27	Mount Horeb	8.14	Solon Springs	0.90
Wyoming	57.7	+ 2.9	Sundance	99	12	Sheridan Creek	9	22	1.47	+ 0.19	Pine Bluff	4.62	Deaver	0.23

* For explanation of the following tables and charts, see this REVIEW, January, 1919, pp. 52-53.

† Other dates also.

TABLE I.—*Climatological data for Weather Bureau Stations, September, 1919.*

Districts and stations.	Elevation of instruments: Barometer above sea level.	Elevation of instruments: Thermometer above ground.	Elevation of instruments: Anemometer above ground.	Pressure: Station, reduced to mean of 24 hours.	Pressure: Sea level, reduced to mean of 24 hours.	Pressure: Departure from normal.	Temperature of the air: Mean max.+mean min.÷2.	Temperature of the air: Departure from normal.	Temperature of the air: Maximum.	Temperature of the air: Date.	Temperature of the air: Mean maximum.	Temperature of the air: Minimum.	Temperature of the air: Date.	Temperature of the air: Mean minimum.	Temperature of the air: Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation: Total.	Precipitation: Departure from normal.	Precipitation: Days with .01 or more.	Wind: Total movement.	Wind: Prevailing direction.	Wind: Maximum velocity: Miles per hour.	Wind: Maximum velocity: Direction.	Wind: Maximum velocity: Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles.								0–10	In.	In.
New England.							**60.6**	**= 0.1**										**82**	**4.42**	**+ 1.2**										**6.2**		
Eastport	76	67	85	29.92	30.00	− .03	55.0	− 0.2	72	30	61	41	27	49	27	52	50	86	3.85	+ 0.9	10	6,748	s.	30	w.	30	6	10	14	8.4	....	....
Greenville, Me.	1,070	6	....	28.84	29.99	....	53.4	....	78	29	62	29	18	44	44	....	....	....	3.71	....	16	....	....	....	....	....	4	11	15	....	....	....
Portland, Me.	103	82	117	29.91	30.03	− .02	57.8	− 1.6	87	8	65	39	16	51	35	54	51	82	3.68	+ 0.5	15	6,539	s.	30	n.	8	7	8	15	6.5	....	....
Concord	288	70	79	29.71	30.02	− .04	59.8	+ 0.7	89	8	70	33	27	49	41	....	....	....	3.07	− 0.1	13	1,874	nw.	15	n.	30	4	10	16	7.2	....	....
Burlington	404	11	48	29.56	29.99	− .07	58.2	− 0.7	84	7	67	32	27	49	30	....	....	....	3.40	0.0	16	8,549	s.	49	s.	20	6	9	15	6.5	....	....
Northfield	876	12	60	....	30.03	− .03	55.3	+ 0.7	84	8	67	26	27	44	46	....	....	85	2.88	+ 0.1	17	5,292	s.	30	s.	25	5	9	16	....	....	....
Boston	125	115	188	29.89	30.03	− .04	63.9	+ 1.2	91	8	72	45	18	56	35	58	55	79	5.83	+ 2.6	12	6,412	sw.	29	sw.	25	9	10	11	5.2	....	....
Nantucket	12	14	90	30.01	30.02	− .06	62.6	− 0.2	79	8	68	48	27	57	18	59	57	86	3.45	+ 0.7	12	9,305	sw.	34	ne.	9	9	8	13	6.5	....	....
Block Island	26	11	46	30.00	30.03	− .05	63.2	− 0.9	80	8	68	48	18	59	20	60	59	87	3.78	+ 0.8	10	9,926	ne.	36	nw.	12	12	7	11	5.4	....	....
Providence	160	215	251	29.86	30.03	− .04	63.0	− 0.2	90	8	71	42	27	55	33	58	55	80	5.80	+ 2.6	11	7,492	nw.	42	nw.	12	11	9	10	5.2	....	....
Hartford	159	122	140	29.86	30.03	− .04	63.4	+ 1.7	90	8	72	41	27	55	31	58	56	82	4.30	+ 0.8	10	4,460	s.	32	sw.	25	10	7	13	5.8	....	....
New Haven	106	74	153	29.92	30.04	− .03	64.2	+ 0.3	91	8	72	43	27	56	24	59	56	78	7.09	+ 3.3	8	5,691	w.	26	sw.	25	13	7	10	5.0	....	....
Middle Atlantic States.							**67.5**	**+ 1.6**										**75**	**1.85**	**− 1.5**										**4.6**		
Albany	97	102	115	29.91	30.01	− .06	62.8	+ 0.5	92	8	72	40	27	54	32	57	54	79	2.99	− 0.2	15	5,164	s.	32	s.	19	8	12	10	5.9	....	....
Binghamton	871	10	84	29.10	30.02	− .05	63.0	+ 3.0	89	8	74	35	27	52	38	....	....	....	1.19	− 1.6	13	3,375	ne.	31	s.	19	8	19	13	5.8	....	....
New York	314	414	454	29.70	30.03	− .05	66.5	0.0	91	8	74	51	27	59	22	65	56	76	3.60	0.0	8	10,059	nw.	49	nw.	12	9	10	11	5.6	....	....
Harrisburg	374	94	104	29.66	30.05	− .03	67.0	+ 2.1	92	8	77	42	27	57	27	60	56	72	1.63	− 1.2	6	3,810	w.	22	nw.	12	15	7	8	4.4	....	....
Philadelphia	117	123	190	29.92	30.05	− .03	68.8	+ 1.4	92	8	77	50	27	61	22	62	58	74	2.82	− 0.6	7	6,301	nw.	26	nw.	3	13	8	9	4.7	....	....
Reading	325	81	98	29.70	30.04	....	67.2	....	92	8	77	43	27	57	29	60	56	74	2.08	− 1.6	5	3,776	n.	23	sw.	25	13	9	8	4.7	....	....
Scranton	805	111	119	29.19	30.04	− .03	63.9	+ 1.7	90	8	74	40	27	54	33	57	54	77	2.21	− 0.6	10	4,165	sw.	35	s.	25	11	8	11	5.6	....	....
Atlantic City	52	37	48	29.98	30.04	− .03	67.9	+ 0.3	86	8	74	50	28	62	24	63	60	79	1.48	− 1.6	6	4,948	sw.	19	sw.	11	14	7	9	4.7	....	....
Cape May	18	13	49	30.05	30.07	.00	68.3	− 0.7	88	9	75	48	28	62	19	63	61	83	1.59	− 1.4	7	4,447	s.	21	nw.	12	18	4	8	3.9	....	....
Sandy Hook	22	10	57	30.01	30.03	....	67.1	....	89	8	73	53	27	62	19	62	59	80	2.80	....	7	9,703	s.	39	w.	12	13	8	9	4.9	....	....
Trenton	190	159	183	29.83	30.03	....	66.0	....	91	8	75	46	27	57	27	60	56	77	2.74	− 0.8	7	6,867	n.	33	nw.	12	11	8	11	5.3	....	....
Baltimore	123	100	113	29.92	30.05	− .03	70.4	+ 1.8	95	8	80	51	28	61	30	62	58	71	2.31	− 1.5	4	4,125	nw.	25	nw.	11	16	6	8	4.1	....	....
Washington	112	62	85	29.93	30.05	− .03	69.4	+ 1.3	94	8	80	46	28	59	30	62	58	76	1.77	− 1.8	6	3,847	nw.	30	nw.	12	12	12	6	4.5	....	....
Lynchburg	681	153	188	29.33	30.07	− .01	69.8	+ 1.4	95	9	83	42	29	57	44	60	56	70	0.47	− 3.2	2	3,610	n.	34	n.	12	20	8	2	3.4	....	....
Norfolk	91	170	205	29.97	30.06	.00	72.6	+ 0.9	91	10	81	58	14	65	26	64	61	74	0.70	− 3.4	3	8,209	s.	40	w.	1	16	8	6	4.4	....	....
Richmond	144	11	52	29.91	30.06	− .01	71.3	+ 0.5	94	9	83	49	27	60	33	63	59	74	0.54	− 2.9	3	4,974	s.	37	nw.	10	12	9	9	4.4	....	....
Wytheville	2,304	49	55	27.74	30.07	00	64.2	+ 0.6	88	9	78	37	29	51	42	56	53	73	1.48	− 1.8	6	2,957	nw.	23	sw.	19	21	6	3	2.9	....	....
South Atlantic States.							**73.7**	**+ 0.8**										**74**	**1.59**	**− 3.0**										**3.5**		
Asheville	2,255	70	84	27.78	30.10	+ .03	66.2	+ 1.2	89	10	79	43	25	53	39	57	53	71	0.30	− 2.7	3	3,834	nw.	29	n.	11	20	8	2	2.4	....	....
Charlotte	779	153	161	29.24	30.06	− .01	72.7	+ 2.0	93	10	84	50	29	62	27	62	58	66	0.84	− 2.4	2	3,053	ne.	22	nw.	11	18	6	6	3.5	....	....
Hatteras	11	12	50	30.04	30.05	− .01	74.0	+ 0.7	85	7	80	61	25	68	19	68	66	78	1.99	− 3.3	4	8,100	ne.	33	w.	12	13	11	6	4.3	....	....
Manteo	12	5	42	....	....	....	72.0	− 1.4	90	9	80	48	14	64	28	....	....	....	2.66	− 1.8	2	....	n.	....	....	....	21	5	4	....	....	....
Raleigh	376	103	110	29.66	30.06	− .01	71.6	+ 1.0	92	9	82	52	28	61	31	64	60	74	0.51	− 2.8	3	4,655	sw.	28	ne.	23	14	12	4	3.8	....	....
Wilmington	78	81	91	29.97	30.05	.00	73.1	0.0	89	11	82	56	28	64	24	66	64	80	1.90	− 3.4	4	4,550	ne.	22	ne.	29	17	8	5	3.5	....	....
Charleston	48	11	92	29.98	30.03	− .01	76.3	+ 0.1	90	23	83	60	29	70	18	70	67	78	1.76	− 3.7	5	7,461	e.	30	n.	30	20	5	5	3.3	....	....
Columbia, S. C.	351	41	57	29.69	30.06	+ .01	74.6	+ 0.9	94	23	85	53	29	64	30	64	60	67	0.08	− 3.4	1	4,419	n.	23	n.	28	21	5	4	2.7	....	....
Greenville, S. C.	1,013	113	122	28.97	30.05	....	72.7	....	92	11	83	53	29	62	29	62	57	64	0.07	....	2	3,878	ne.	35	n.	11	19	10	1	2.6	....	....
Augusta	180	62	77	29.84	30.03	− .02	75.3	+ 0.9	94	11	87	53	29	64	32	67	63	73	0.06	− 3.6	1	3,523	ne.	21	ne.	30	20	3	7	3.2	....	....
Savannah	65	150	194	29.96	30.02	− .01	76.0	+ 0.6	92	23	83	57	29	68	23	70	68	83	1.73	− 3.8	4	6,952	ne.	42	ne.	30	12	13	5	4.5	....	....
Jacksonville	43	200	245	29.95	30.00	.00	7.47	+ 0.1	91	12	83	64	29	72	19	72	71	85	5.63	− 2.4	13	8,824	ne.	36	ne.	28	11	13	6	4.9	....	....
Florida Peninsula.							**81.2**	**0.0**										**78**	**8.26**	**+ 0.3**										**5.7**		
Key West	22	10	64	29.87	29.89	− .05	82.4	− 0.1	90	25	87	73	10	78	15	76	73	77	14.26	+ 7.5	12	8,582	e.	110	e.	10	12	9	9	5.0	....	....
Miami	25	71	79	29.91	29.94	....	80.4	− 1.1	90	26	86	69	1	75	18	75	73	78	3.72	− 5.9	13	6,884	e.	46	se.	9	8	10	12	6.0	....	....
Sand Key	23	39	72	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Tampa	35	79	92	29.92	29.95	− .02	80.8	+ 1.1	93	6	89	67	29	72	23	73	71	79	6.82	− 0.6	10	4,968	ne.	34	e.	20	2	21	7	6.2	....	....
East Gulf States.							**76.5**	**+ 1.7**										**72**	**0.88**	**− 3.0**										**4.1**		
Atlanta	1,174	190	216	28.84	30.05	00	74.2	+ 2.1	91	10	84	56	29	65	26	63	58	63	1.12	− 2.4	5	5,865	e.	30	w.	11	22	4	4	2.7	....	....
Macon	370	78	87	29.6	30.03	00	75.0	+ 2.1	94	11	86	54	29	64	30	66	62	70	0.77	− 2.6	4	3,683	ne.	19	ne.	28	16	8	6	3.5	....	....
Thomasville	273	49	58	29.71	30.00	− .01	77.6	+ 0.8	93	18	87	57	29	68	25	69	66	77	0.34	− 3.9	6	3,020	ne.	19	e.	6	10	16	4	4.6	....	....
Pensacola	56	140	182	29.93	29.99	00	77.8	− 0.1	89	10	84	60	30	72	26	70	67	74	0.76	− 4.5	7	9,102	ne.	39	se.	13	9	11	10	5.4	....	....
Anniston	741	9	57	29.28	30.07	+ .04	73.6	+ 2.3	9	10	87	52	30	61	38	....	....	....	0.55	− 3.0	2	3,000	se.	20	se.	13	23	6	1	2.3	....	....
Birmingham	700	11	48	29.29	30.05	+ .02	75.9	+ 1.9	95	11	87	55	2[illegible]	65	30	64	60	69	1.09	− 2.4	4	3,61[illegible]	n.	23	se.	20	18	9	3	2.9	....	....
Mobile	57	125	161	29.93	29.99	− .03	78.6	+ 2.1	9	11	87	62	29	70	25	70	67	76	1.10	− 3.9	8	6,483	n.	35	e.	13	10	16	4	4.6	....	....
Montgomery	223	100	112	29.78	30.03	+ .01	77.1	+ 1.3	9	11	87	56	29	67	30	67	62	67	0.13	− 2.8	2	3,955	e.	22	sw.	20	17	11	2	3.1	....	....
Corinth	469	6	....	....	....	....	74.9	....	98	11	89	47	24	61	38	....	....	....	0.40	....	4	....	n.	....	....	....	1[illegible]	1[illegible]	2	....	....	....
Jackson	30	5	....	....	....	....	77.5	....	97	11	90	54	30	65	39	....	....	....	0.31	....	3	....	ne.	....	....	....	18	8	4	....	....	....
Meridian	375	85	93	29.62	30.01	− .01	75.4	+ 2.7	92	11	85	56	29	66	29	67	64	74	0.22	− 3.2	2	3,0[illegible]0	e.	18	e.	13	12	14	4	4.4	....	....
Vicksburg	247	65	74	29.7	30.02	00	76.3	+ 1.5	95	11	86	57	2	67	28	69	67	81	0.68	− 2.7	4	3,973	n.	2	nw.	22	11	9	10	5.1	....	....
New Orleans	53	76	84	29.92	29.97	− .01	80.2	+ 2.2	91	11	86	69	26	74	19	71	68	73	2.93	− 1.9	9	5,244	ne.	32	se.	13	11	5	14	6.1	....	....
West Gulf States.							**76.7**	**+ 1.0**										**77**	**4.01**	**+ 0.6**										**4.9**		
Shreveport	249	77	93	29.74	30.01	+ .01	76.4	+ 0.7	93	11	85	59	2	68	27	69	66	77	2.16	− 1.1	6	4,250	e.	23	s.	20	14	9	7	4.6	....	....
Bentonville	1,303	11	4[illegible]	28.68	30.02	00	71.4	+ 2.5	91	10	84	44	13	59	37	....	....	....	1.6	− 1.8	4	3,097	s.	22	se.	18	16	6	8	4.4	....	....
Fort Smith	457	79	91	29.52	30.00	− .01	75.6	+ 2.9	97	10	86	52	2	65	29	66	62	71	0.56	− 2.6	5	4,22	e.	26	s.	18	14	8	8	4.9	....	....
Little Rock	357	139	147	29.65	30.02	− .01	75.3	+ 2.2	95	10	84	55	26	66	2	66	62	68	2.78	− 0.5	4	4,928	s.	30	s.	18	12	8	10	4.9	....	....
Brownsville	57	4	26	....	....	....	82.3	....	100	12	92	66	5	72	30	....	....	....	7.69	....	11	....	....	....	....	....	....	....	....	....	....	....
Corpus Christi	20	69	77	29.89	29.91	− .04	80.2	+ 1.2	9	11	86	68	23	7	21	74	73	82	5.81	+ 1.8	13	10,805	se.	72	ne.	14	8	1[illegible]	8	5.5	....	....
Dallas	512	109	117	29.45	29.99	....	76.2	....	96	11	8	61	22	68	23	....	....	....	3.89	....	7	5,736	se.	29	ne.	14	8	10	12	2.2	....	....
Fort Worth	670	106	114	29.25	29.96	− .03	75.6	− 1.1	95	11	8	59	22	68	23	68	66	77	4.12	+ 1.2	8	6,228	se.	29	n.	19	8	11	11	5.6	....	....
Galveston	5[illegible]	106	114	29.90	29.96	− .02	80.0	+ 0.6	91	10	8	68	4	76	14	73	71	76	5.29	− 0.1	7	8,95[illegible]	se.	53	e.	1[illegible]	15	11	4	4.0	....	....
Houston	138	111	121	29.80	29.95	....	79.0	+ 0.5	93	11	86	64	2	72	20	....	....	....	8.68	....	9	5,9[illegible]6	se.	38	e.	1	8	17	5	4.9	....	....
Palestine	510	6	72	29.[illegible]6	29.98	− .01	76.3	+ 1.5	93	10	85	57	2	68	26	69	66	79	4.12	+ 0.9	4	4,968	e.	28	s.	20	10	9	11	5.	....	....
Port Arthur	3[illegible]	58	66	29.91	29.95	....	78.4	....	92	1	83	62	2	72	20	72	70	80	3.98	....	8	6,898	e.	43	se.	1	14	9	7	4.6	....	....
San Antonio	701	119	1 2	29.22	29.9	− .02	77.8	+ 0.7	9	11	86	61	23	70	2	70	68	81	7.61	+ 4.7	13	6,005	se.	52	se.	15	6	1	10	6.1	....	....
Taylor	582	55	65	29.38	29.99	+ .02	76.5	− 0.4	94	11	85	59	22	68	24	....	....	....	5.99	+ 3.0	9	5,289	se.	30	ne.	14	3	14	13	6.8	....	....

TABLE I.—*Climatological data for Weather Bureau Stations, September, 1919*—Continued.

Districts and stations.	Elevation of instruments: Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Pressure: Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Temperature of the air: Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation: Total.	Departure from normal.	Days with .01 or more.	Wind: Total movement.	Prevailing direction.	Maximum velocity: Miles per hour.	Direction.	Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles.								0-10	In.	In.
Ohio Valley and Tennessee.							**70.5**	**+ 2.7**										**68**	**1.70**	**− 1.1**										**4.1**		
Chattanooga	762	189	213	29.26	30.07	+ .01	73.8	+ 2.6	93	9	85	54	26	63	30	62	57	63	0.04	− 3.2	2	4,692	s.	24	s.	19	19	5	6	3.4	......	....
Knoxville	996	102	111	29.02	30.06	.00	72.0	+ 2.6	93	10	81	50	25	60	31	62	57	67	0.96	− 1.8	4	3,289	ne.	24	s.	19	21	3	6	3.0	......	....
Memphis	399	76	97	29.6	30.06	+ .03	76.2	+ 3.4	95	10	85	56	13	67	30	67	63	70	1.34	− 1.7	4	4,460	sw.	29	sw.	21	14	11	5	4.1	......	....
Nashville	516	168	191	29.49	30.07	+ .01	72.8	+ 1.3	92	10	84	52	2	62	30	63	58	67	1.33	− 2.4	2	4,965	nw.	29	sw.	19	19	8	3	3.2	......	....
Lexington	989	193	230	29.02	30.07	.00	71.5	+ 3.6	92	10	81	49	26	62	29	......	......	......	1.12	− 1.3	5	8,457	sw.	48	sw.	19	18	6	6	3.5	......	....
Louisville	525	219	255	29.49	30.06	.00	73.0	+ 3.1	95	10	81	49	26	62	32	63	59	67	2.53	− 0.1	5	7,186	s.	46	n.	11	20	7	3	3.4	......	....
Evansville	431	139	175	29.59	30.05	− .01	74.4	+ 4.7	97	10	85	50	26	61	32	63	56	60	3.59	+ 0.9	6	6,932	sw.	45	w.	19	13	15	2	3.9	......	....
Indianapolis	822	194	230	29.17	30.05	− .01	70.3	+ 4.6	93	9	80	46	26	60	32	60	55	64	1.86	− 1.2	8	7,438	sw.	34	sw.	20	14	10	6	4.3	......	....
Terre Haute	575	96	129	29.42	30.03	......	70.8	......	95	9	82	45	26	60	34	61	55	64	1.56	......	6	6,138	sw.	40	nw.	10	13	15	2	4.0	......	....
Cincinnati	628	11	51	29.38	30.06	− .01	69.6	+ 4.9	95	9	82	44	26	58	35	60	54	64	3.79	+ 1.5	7	4,319	ne.	37	sw.	19	15	9	6	4.0	......	....
Columbus	82	179	222	29.19	30.06	− .01	68.1	+ 2.2	92	9	78	42	26	58	29	60	55	67	1.15	− 1.4	6	6,931	se.	41	nw.	10	12	9	9	4.9	......	....
Dayton	899	181	216	29.08	30.02	......	68.8	+ 1.4	93	9	80	44	26	58	34	59	54	65	1.26	− 1.2	6	5,862	sw.	47	sw.	19	16	10	4	3.8	......	....
Pittsburgh	842	353	410	29.16	30.06	− .02	66.4	+ 0.3	88	7	76	45	26	57	28	59	55	73	1.6	− 0.8	6	6,257	nw.	49	nw.	11	11	6	13	5.4	......	....
Elkins	1,947	41	50	28.06	30.10	+ .02	62.0	+ 0.1	86	9	75	35	29	49	45	55	53	87	2.28	− 0.6	6	2,533	w.	20	w.	16	7	13	10	5.9	......	....
Parkersburg	638	77	82	29.43	30.08	.00	68.6	+ 2.5	91	9	80	45	14	57	34	60	56	72	0.98	− 1.7	5	3,047	nw.	31	s.	19	11	10	9	5.4	......	....
Lower Lake Region.							**64.7**	**+ 1.6**										**70**	**2.23**	**− 0.6**										**5.4**		
Buffalo	767	247	280	29.19	30.01	− .05	63.1	+ 0.2	80	21	70	44	26	56	26	57	54	75	1.47	− 1.7	15	11,147	sw.	74	sw.	19	8	7	15	6.3	......	....
Canton	448	10	61	29.49	29.97	......	58.8	− 0.5	85	21	68	35	27	49	30	......	......	......	4.69	+ 1.9	14	6,993	sw.	41	sw.	20	8	9	13	6.2	......	....
Oswego	335	76	91	29.63	29.99	− .07	62.2	− 0.5	89	7	70	40	27	55	28	57	53	74	2.47	− 0.3	10	6,710	s.	33	ne.	12	7	10	13	6.2	......	....
Rochester	523	97	113	29.46	30.02	− .04	63.4	+ 1.5	89	7	72	42	26	55	33	56	52	71	1.26	− 1.1	13	5,532	sw.	30	sw.	20	9	10	11	5.7	......	....
Syracuse	597	97	113	29.37	30.02	− .05	63.0	+ 1.4	89	7	71	39	27	55	29	......	......	......	1.60	− 1.2	14	7,332	s.	47	s.	19	5	15	10	6.3	......	....
Erie	714	130	166	29.26	30.02	− .04	65.6	+ 1.7	87	7	73	47	27	58	28	58	54	70	1.27	− 2.2	9	9,389	sw.	40	sw.	19	7	16	7	5.6	......	....
Cleveland	762	190	201	29.22	30.04	− .02	66.4	+ 2.1	88	8	74	48	27	59	29	59	54	69	1.79	− 1.4	8	8,373	sw.	44	ne.	11	9	13	8	5.3	......	....
Sandusky	629	62	103	29.36	30.04	− .02	67.6	+ 2.3	90	8	76	49	27	59	29	......	......	......	2.17	− 0.5	8	8,054	sw.	46	nw.	11	13	10	7	4.7	......	....
Toledo	628	208	243	29.36	30.04	− .02	67.6	+ 3.5	91	8	77	44	26	58	28	58	53	66	1.51	− 0.8	6	9,406	sw.	64	s.	19	14	11	5	4.0	......	....
Fort Wayne	856	113	124	29.13	30.05	......	67.6	+ 2.1	93	9	78	42	26	57	32	58	52	65	2.61	......	5	5,994	sw.	32	nw.	11	12	11	7	4.6	......	....
Detroit	730	218	245	29.25	30.03	− .03	66.8	+ 3.7	90	8	76	45	26	58	25	57	53	67	4.09	+ 1.6	9	7,693	sw.	39	sw.	19	12	10	8	4.8	......	....
Upper Lake Region.							**61.6**	**+ 2.7**										**75**	**3.06**	**− 0.2**										**5.9**		
Alpena	609	13	92	29.33	29.99	− .04	60.0	+ 2.7	95	8	70	35	26	51	33	55	52	78	1.55	− 1.9	13	7,885	nw.	40	nw.	11	6	15	9	6.3	......	....
Escanaba	612	54	60	29.32	29.98	− .03	58.1	+ 1.1	79	7	66	32	26	51	25	54	51	82	2.15	− 1.4	13	6,506	s.	31	s.	26	11	9	10	5.1	......	....
Grand Haven	632	54	89	29.33	30.00	− .04	62.9	+ 1.8	82	8	70	40	26	56	27	58	54	75	4.85	+ 1.7	10	7,821	s.	33	w.	24	8	10	12	5.6	......	....
Grand Rapids	707	70	87	29.26	30.02	− .03	65.3	+ 3.5	92	8	74	41	26	56	32	57	52	69	3.86	+ 0.7	11	3,821	nw.	23	nw.	11	8	11	11	5.9	......	....
Houghton	684	62	99	29.25	29.97	− .03	56.4	+ 0.3	92	7	64	35	26	49	37	......	......	......	1.33	− 2.2	15	6,025	e.	63	nw.	20	6	3	21	7.6	......	....
Lansing	878	11	62	29.08	30.02	......	63.8	+ 2.5	90	8	75	34	26	52	34	56	53	76	2.61	0.0	11	3,677	sw.	23	s.	19	7	14	9	5.5	......	....
Ludington	637	60	66	29.31	30.00	......	61.2	......	79	7	68	39	26	55	28	56	53	76	4.02	......	11	7,525	s.	35	s.	20	11	7	12	5.0	......	....
Marquette	734	77	111	29.19	29.99	− .01	59.2	+ 2.4	93	7	67	36	26	52	28	53	50	77	2.49	− 1.0	14	7,390	nw.	38	sw.	27	5	3	22	7.7	......	....
Port Huron	638	70	120	29.32	30.01	− .05	64.1	+ 3.2	92	8	73	38	26	55	31	57	54	75	3.77	+ 1.1	9	7,731	sw.	32	sw.	19	9	14	7	5.0	......	....
Saginaw	641	69	77	29.32	30.01	......	64.0	......	91	8	74	36	26	54	29	56	51	72	2.52	− 0.6	9	5,741	sw.	35	s.	19	10	13	7	5.0	......	....
Sault Ste. Marie	614	11	52	29.28	29.97	− .05	57.8	+ 3.5	89	7	66	35	30	49	36	54	52	86	4.05	+ 0.6	17	4,995	nw.	36	nw.	25	4	9	17	7.2	......	....
Chicago	823	140	310	29.15	30.02	− .02	68.9	+ 4.3	93	8	76	52	26	62	25	59	53	62	3.85	+ 0.8	9	8,145	sw.	36	s.	20	11	12	7	4.8	......	....
Green Bay	617	109	144	29.31	29.97	− .05	62.6	+ 3.5	90	8	71	40	26	54	28	56	52	74	2.97	− 0.2	9	7,567	s.	32	s.	20	5	11	14	6.6	......	....
Milwaukee	681	119	133	29.26	30.00	− .03	65.5	+ 4.0	93	8	73	46	26	58	25	58	54	71	5.36	+ 2.4	12	6,702	sw.	33	sw.	28	13	7	10	4.9	......	....
Duluth	1,133	11	47	28.75	29.97	− .01	55.8	+ 1.7	77	19	64	36	25	48	29	50	47	82	1.42	− 2.1	11	7,987	ne.	44	nw.	24	8	9	13	6.0	......	....
North Dakota.							**59.1**	**+ 2.0**										**67**	**0.90**	**− 0.5**										**5.1**		
Moorhead	940	8	57	28.97	29.97	+ .01	60.6	+ 4.0	91	7	72	32	25	49	32	53	49	75	1.34	− 1.0	5	5,770	se.	30	nw.	23	13	7	10	4.6	......	....
Bismarck	1,674	8	57	28.21	29.98	+ .04	61.0	+ 3.9	93	6	73	34	25	49	45	51	44	62	0.34	− 0.8	4	7,373	nw.	32	nw.	20	13	8	9	4.7	......	....
Devils Lake	1,482	11	44	28.37	29.94	.00	57.1	+ 1.5	86	6	68	30	25	46	32	49	44	71	0.95	− 0.4	4	7,226	nw.	36	nw.	24	9	11	10	5.3	......	....
Ellendale	1,457	10	56	28.40	29.96	......	60.5	......	94	5	73	30	25	48	41	51	46	67	0.19	......	4	9,539	nw.	41	s.	12	6	11	13	6.2	......	....
Grand Forks	835	12	89	......	......	......	58.5	......	91	7	70	29	25	47	32	52	......	......	2.23	......	8	......	nw.	39	sw.	24	12	9	9	......	......	....
Williston	1,878	41	48	27.97	29.94	+ .01	58.0	− 1.5	88	11	69	32	27	47	45	49	42	60	0.99	+ 0.1	4	6,557	se.	40	w.	6	9	15	6	4.8	......	....
Upper Mississippi Valley.							**68.4**	**+ 3.5**										**71**	**4.16**	**+ 0.8**										**4.6**		
Minneapolis	918	10	208	28.96	29.94	......	64.3	......	91	7	73	41	25	55	34	......	......	......	1.47	− 2.2	11	8,052	s.	48	s.	26	9	10	11	6.0	......	....
St. Paul	837	236	261	29.07	29.97	− .02	63.9	+ 3.0	89	20	73	41	25	55	36	......	......	......	1.25	− 2.2	8	8,347	se.	51	s.	26	11	13	6	5.1	......	....
La Crosse	714	11	48	29.22	29.98	− .03	64.4	+ 2.7	91	7	74	42	23	55	34	......	......	......	2.35	− 1.8	9	3,056	se.	21	s.	26	12	4	14	5.8	......	....
Madison	974	70	78	28.98	30.01	− .02	64.2	+ 3.1	91	8	72	44	26	56	30	57	53	72	6.83	+ 3.6	10	5,992	s.	28	s.	26	9	7	14	6.1	......	....
Wausau	1,247	4	....	28.66	29.99	......	59.8	......	87	8	69	35	26	50	35	......	......	......	2.76	......	12	......	n.	....	....	....	10	8	12	5.5	......	....
Charles City	1,015	10	49	28.92	29.99	− .01	65.0	+ 3.3	91	8	75	42	25	55	35	58	54	77	3.94	+ 1.1	12	4,316	s.	26	s.	26	14	7	9	5.1	......	....
Davenport	606	71	79	29.36	30.01	− .02	68.8	+ 4.1	92	9	79	48	23	59	30	60	56	71	7.23	+ 4.1	9	4,564	sw.	25	s.	20	15	9	6	4.1	......	....
Des Moines	861	84	97	29.08	30.00	− .02	68.9	+ 3.9	94	9	79	45	23	59	32	60	56	71	7.65	+ 4.6	7	5,075	sw.	32	sw.	5	12	8	10	5.0	......	....
Dubuque	698	81	96	29.28	30.02	− .01	66.1	+ 2.5	91	8	75	43	26	57	29	58	55	74	5.35	+ 1.8	10	3,917	s.	22	s.	26	12	7	11	5.1	......	....
Keokuk	614	64	78	29.36	30.02	− .01	70.8	+ 4.4	94	9	81	47	26	61	32	61	56	66	4.69	+ 0.7	5	4,766	s.	29	se.	18	18	7	5	3.3	......	....
Cairo	356	87	93	29.65	30.03	− .02	73.8	+ 3.6	95	10	84	52	24	64	27	65	61	72	1.80	− 0.7	4	4,697	s.	32	sw.	19	12	11	7	4.6	......	....
Peoria	609	11	45	29.37	30.03	− .01	68.2	+ 3.9	94	9	80	43	26	57	32	60	56	76	3.48	+ 0.4	8	3,548	s.	21	w.	19	19	5	6	3.2	......	....
Springfield, Ill.	644	10	91	29.34	30.01	− .04	70.5	+ 4.1	96	10	82	45	26	59	31	61	56	70	2.74	− 0.6	7	5,293	s.	36	se.	28	13	12	5	4.2	......	....
Hannibal	534	74	109	29.45	30.02	− .01	70.6	+ 2.7	95	10	82	49	23	60	37	......	......	......	3.28	− 0.3	5	5,796	sw.	39	sw.	18	18	6	6	3.2	......	....
St. Louis	567	265	303	29.42	30.02	− .02	73.6	+ 3.6	96	10	83	50	26	64	26	62	56	60	6.13	+ 3.2	6	8,130	sw.	48	s.	20	20	7	3	2.9	......	....
Missouri Valley.							**69.1**	**+ 4.2**										**67**	**2.68**	**− 0.1**										**4.3**		
Columbia, Mo.	781	11	84	29.20	30.02	− .01	71.1	+ 3.3	96	10	82	48	23	60	33	......	......	......	3.31	+ 0.5	7	4,653	se.	36	sw.	18	20	4	6	3.0	......	....
Kansas City	963	161	181	28.97	29.99	− .03	72.4	+ 4.9	96	10	82	51	23	63	29	62	57	64	2.26	− 1.5	5	7,232	s.	33	se.	18	20	4	6	3.3	......	....
St. Joseph	967	11	49	28.96	29.98	......	71.2	......	94	9	82	49	23	61	34	62	57	70	4.40	......	7	5,072	s.	24	se.	26	20	3	7	3.0	......	....
Springfield, Mo.	1,324	98	104	28.64	30.03	.00	72.6	+ 4.7	95	10	83	52	22	62	29	62	57	66	1.62	− 2.1	4	6,641	s.	35	s.	18	20	7	3	2.6	......	....
Iola	984	11	50	28.97	29.99	− .02	73.0	+ 4.4	98	10	86	45	21	60	41	......	......	......	1.02	− 2.3	4	4,504	s.	26	n.	10	12	10	8	4.7	......	....
Topeka	987	92	107	......	......	......	72.1	......	96	10	83	48	23	61	37	......	......	......	2.50	− 1.1	4	6,962	sw.	29	sw.	18	17	8	5	3.3	......	....
Drexel	1,299	10	54	28.56	29.9[illegible]	......	68.3	......	95	9	79	42	22	58	35	59	56	76	3.80	......	9	7,037	s.	42	sw.	26	12	8	10	5.0	......	....
Lincoln	1,189	11	84	28.71	29.95	− .01	71.0	+ 5.8	99	9	82	47	23	60	33	60	55	67	5.75	+ 3.1	8	6,920	s.	30	s.	26	15	3	12	4.9	......	....
Omaha	1,105	115	122	28.80	29.97	− .03	70.8	+ 5.0	98	9	80	48	22	61	30	60	56	67	5.28	+ 2.2	9	5,101	s.	27	n.	24	16	3	11	4.8	......	....
Valentine	2,598	47	54	27.27	29.96	.00	65.6	+ 3.3	96	5	78	36	25	53	40	55	48	63	1.04	......	9	7,018	s.	33	s.	12	13	12	5	4.3	......	....
Sioux City	1,135	94	164	28.76	29.96	− .02	67.2	+ 3.1	92	7	77	42	25	58	35	58	54	72	2.56	+ 0.1	10	8,096	s.	45	s.	26	9	8	13	5.5	......	....
Huron	1,306	59	74	28.58	29.97	+ .01	63.5	+ 4.1	94	5	75	35	25	52	40	55	50	71	0.77	− 0.9	8	7,065	se.	36	s.	13	12	8	10	4.6	......	....
Pierre	1,572	70	75	28.30	29.94	− .01	66.4	+ 3.6	97	6	78	38	25	55	37	55	47	60	1.59	+ 0.5	3	6,292	e.	30	se.	12	10	8	12	5.2	......	....
Yankton	1,233	49	57	28.64	29.94	− .04	66.8	+ 3.5	94	7	77	40	25	56	39	......	......	......	2.87	+ 0.4	10	4,939	s.	27	s.	26	8	8	14	6.1	......	....

TABLE I.—*Climatological data for Weather Bureau Stations, September, 1919*—Continued.

Districts and stations.	Elevation of instruments. Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Pressure. Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Temperature of the air. Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation. Total.	Departure from normal.	Days with .01 or more.	Wind. Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Direction.	Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Ft.	Ft.	Ft.	In.	In.	In.	° F.	° F.	° F.		° F.	° F.		° F.	° F.	° F.	° F.	%	In.	In.		Miles.								0-10	In.	In.
Northern Slope.							**59.2**	**+ 1.8**										**62**	**1.37**	**+ 0.3**										**4.4**		
Billings	3,140	5	...	...	...	...	58.2	...	87	11	73	27	29	43	51	...	...	...	0.60	...	8	...	sw.	...	...	...	13	15	2	...	...	...
Havre	2,505	11	44	27.34	29.96	+ .02	57.0	− 0.6	94	11	70	26	29	45	49	48	42	66	0.79	− 0.2	12	5,274	e.	37	n.	19	14	8	8	4.5	...	...
Helena	4,110	87	112	25.80	29.96	− .01	57.0	+ 0.8	89	11	69	28	28	45	40	46	37	53	0.57	− 0.5	6	6,002	sw.	40	sw.	4	10	9	11	5.0	...	...
Kalispell	2,962	11	34	26.92	29.96	.00	54.0	+ 0.1	85	3	67	24	29	41	41	45	37	58	0.50	− 0.8	6	3,931	nw.	31	ne.	26	13	9	8	4.6	...	...
Miles City	2,371	26	48	27.45	29.98	+ .03	63.2	+ 2.0	95	11	75	34	29	52	39	54	49	70	1.32	+ 0.1	10	4,479	n.	30	w.	20	12	13	5	4.3	...	...
Rapid City	3,259	50	58	26.61	29.98	+ .02	63.0	+ 3.9	92	6	75	36	22	51	41	53	46	60	2.27	+ 1.0	7	5,514	n.	33	nw.	7	14	9	7	4.3	...	...
Cheyenne	6,088	84	101	24.07	29.9	− .02	59.0	+ 1.8	81	1	71	32	21	47	36	50	44	66	1.76	+ 0.8	8	6,771	w.	36	nw.	1	12	12	6	4.7	...	...
Lander	5,372	60	68	24.67	29.9	− .02	59.8	+ 4.6	88	11	74	32	22	45	39	47	37	50	1.01	0.0	9	3,707	sw.	30	sw.	5	16	9	5	3.7	...	...
Sheridan	3,790	10	47	26.10	29.96	...	59.6	...	91	11	74	30	22	45	49	50	44	66	1.11	...	7	3,356	nw.	34	sw.	4	19	2	9	4.1	...	...
Yellowstone Park	6,200	11	48	23.92	29.98	+ .01	52.0	− 1.4	78	11	65	26	28	39	39	42	34	60	2.51	+ 1.5	13	5,103	s.	30	s.	11	9	15	6	4.6	...	...
North Platte	2,821	11	51	27.09	29.98	+ .01	67.8	+ 4.6	97	5	80	36	23	55	43	56	52	68	1.56	+ 0.1	8	4,647	s.	24	ne.	2	14	8	8	4.5	...	...
Middle Slope.							**70.8**	**+ 3.3**										**64**	**1.40**	**− 0.6**										**4.4**		
Denver	5,292	106	113	24.77	29.95	− .01	64.4	+ 1.7	86	4	76	36	22	53	37	52	45	60	1.04	+ 0.2	8	4,605	s.	36	n.	20	10	12	8	5.0	...	...
Pueblo	4,685	80	86	25.31	29.92	− .04	67.5	+ 3.1	95	1	81	35	23	54	41	5[illegible]	47	59	2.04	+ 1.[illegible]	8	3,697	nw.	37	nw.	5	7	15	8	5.3	...	...
Concordia	1,392	50	58	28.52	29.96	− .03	71.[illegible]	+ 3.3	100	9	82	46	23	60	33	60	5[illegible]	63	3.03	+ 0.4	[illegible]	5,851	s.	28	s.	7	13	10	7	4.4	...	...
Dodge City	2,509	11	51	27.40	29.96	− .02	73.1	+ 4.9	96	10	86	43	23	60	35	61	56	6[illegible]	1.01	− 0.8	2	7,683	s.	35	ne.	21	18	9	3	3.4	...	...
Wichita	1,358	139	158	28.56	29.96	− .04	74.3	+ 4.5	98	10	85	48	23	64	31	63	58	64	0.23	− 2.9	2	9,771	s.	43	nw.	18	1[illegible]	12	4	3.7	...	...
Altus	1,410	5	...	...	...	...	76.4	...	101	10	88	54	22	65	35	...	...	...	2.56	...	8	...	e.	...	...	...	15	1	14	...	...	...
Muskogee	652	4	...	...	...	...	75.4	...	100	10	88	42	24	63	3[illegible]	...	...	...	1.65	...	5	...	se.	...	...	...	12	11	7	...	...	...
Oklahoma	1,214	10	47	28.73	29.99	.00	74.3	+ 2.2	98	10	85	50	22	64	35	65	61	73	1.03	− 1.7	3	8,475	s.	34	s.	27	12	10	8	4.9	...	...
Southern Slope.							**73.4**	**+ 0.6**										**70**	**5.59**	**+ 3.0**										**5.0**		
Abilene	1,738	10	52	28.18	29.95	− .01	75.3	+ 1.1	97	11	85	55	22	66	30	66	62	73	1.72	− 1.4	11	6,502	s.	26	e.	15	11	9	10	5.8	...	...
Amarillo	3,676	10	49	26.30	29.96	.00	71.2	+ 3.5	99	2	85	47	23	59	3[illegible]	60	55	68	4.58	+ 2.2	3	7,730	s.	31	nw.	21	13	14	3	4.3	...	...
Del Rio	944	6	71	28.92	29.89	− .03	77.2	− 1.7	97	11	83	57	2[illegible]	69	23	...	...	...	9.74	+ 7.2	9	6,762	se.	58	e.	15	9	14	7	5.6	...	...
Roswell	3,566	75	85	26.37	29.92	.00	70.0	− 0.3	94	3	82	48	2[illegible]	58	35	60	55	68	6.33	+ 4.0	7	4,649	s.	33	nw.	18	15	9	6	4.2	...	...
Southern Plateau.							**71.0**	**+ 0.5**										**51**	**1.56**	**+ 0.6**										**2.9**		
El Paso	3,762	110	133	26.17	29.86	− .02	72.6	− 0.1	92	2	82	48	2[illegible]	63	27	60	53	60	3.30	+ 1.8	11	6,398	e.	46	ne.	12	13	9	8	4.5	...	...
Santa Fe	7,013	57	66	23.32	29.89	− .0[illegible]	61.[illegible]	+ 0.8	8[illegible]	1	71	37	23	51	29	50	4[illegible]	62	2.53	+ 0.9	10	4,520	e.	29	sw.	13	13	12	5	4.6	...	...
Flagstaff	6,908	8	57	23.40	29.85	− .0[illegible]	56.7	+ 1.2	79	3	70	3[illegible]	2[illegible]	4[illegible]	40	48	...	...	1.5[illegible]	...	7	...	sw.	27	w.	30	17	11	2	...	...	...
Phoenix	1,108	11	81	28.64	29.77	− .0[illegible]	81.5	+ 0.1	106	3	94	6[illegible]	2[illegible]	69	37	67	60	55	1.93	+ 0.9	5	3,778	e.	19	s.	6	21	7	2	2.2	...	...
Yuma	141	9	54	29.59	29.73	− .05	81.2	+ 0.3	106	3	98	60	30	71	36	68	61	54	0.03	− 0.1	1	3,617	w.	30	s.	6	22	4	4	2.1	...	...
Independence	3,957	11	42	25.89	29.85	− .01	69.8	+ 0.7	91	15	85	41	30	55	39	50	28	26	T.	− 0.1	0	5,327	s.	30	se.	28	26	4	0	1.3	...	...
Needles	488	4	...	...	...	...	84.5	...	112	21	...	60	30	...	48	...	...	...	1.37	...	5	...	...	...	e.	...	21	4	5	...	...	...
Middle Plateau.							**63.1**	**+ 0.7**										**44**	**1.24**	**+ 0.6**										**3.0**		
Reno	4,532	74	81	25.42	29.86	− .09	59.5	− 0.2	88	24	76	36	12	43	47	45	31	42	0.40	+ 0.1	2	5,051	w.	35	w.	27	22	4	4	2.3	...	...
Tonopah	6,090	12	20	24.06	29.86	...	63.0	...	82	13	74	33	30	52	32	46	29	35	0.39	− 0.1	3	7,671	se.	34	se.	8	20	10	0	2.2	...	...
Winnemucca	4,344	18	56	25.56	29.90	− .03	59.4	− 1.1	87	15	77	30	24	41	56	44	30	40	0.40	+ 0.1	3	4,493	ne.	31	sw.	27	21	7	2	2.4	...	...
Modena	5,479	10	43	24.61	29.87	− .05	61.2	+ 1.0	84	12	75	32	23	48	43	49	38	52	3.29	+ 2.2	7	8,567	sw.	56	sw.	6	17	8	5	3.2	...	...
Salt Lake City	4,360	163	203	25.58	29.88	− .07	66.8	+ 1.7	90	11	77	47	23	56	32	54	44	49	1.76	+ 0.9	12	6,154	se.	48	e.	3	14	7	9	4.0	...	...
Grand Junction	4,602	82	96	25.38	29.91	− .04	68.6	+ 2.2	90	11	81	41	23	56	35	54	44	50	1.17	+ 0.2	7	4,306	se.	30	sw.	30	13	10	7	4.2	...	...
Northern Plateau.							**60.8**	**− 0.3**										**51**	**0.94**	**+ 0.2**										**3.5**		
Baker	3,471	48	53	26.41	29.97	− .02	56.4	− 0.6	86	15	72	29	29	41	45	46	35	52	0.26	− 0.5	8	4,301	se.	36	sw.	4	18	9	3	2.4	...	...
Boise	2,739	78	86	27.10	29.93	− .04	62.2	+ 0.3	94	3	76	38	28	48	40	50	38	46	0.79	+ 0.4	3	3,494	nw.	39	ne.	16	17	7	6	3.5	...	...
Lewiston	757	40	48	29.15	29.95	− .03	63.0	− 0.5	91	3	78	36	29	48	43	...	...	...	0.73	+ 0.1	6	1,998	e.	21	w.	19	13	10	7	4.0	...	...
Pocatello	4,477	60	68	25.45	29.90	− .06	61.5	+ 0.9	88	10	74	31	22	49	43	49	39	51	2.13	+ 1.2	10	6,321	se.	44	s.	3	13	10	7	3.9	...	...
Spokane	1,929	101	110	27.93	29.97	− .01	58.8	0.0	87	3	72	28	29	45	41	48	38	52	0.46	− 0.6	5	3,824	ne.	30	sw.	19	16	10	4	4.0	...	...
Walla Walla	991	57	65	28.89	29.96	− .04	63.0	− 2.4	88	2	75	39	29	51	37	52	43	52	1.26	+ 0.3	7	3,054	s.	22	w.	11	20	6	4	3.0	...	...
North Pacific Coast Region.							**59.0**	**+ 1.4**										**76**	**2.34**	**− 0.1**										**4.6**		
North Head	211	11	56	29.76	29.99	− .04	58.0	+ 1.8	84	14	63	48	28	53	31	54	52	84	2.18	+ 0.3	9	8,483	n.	72	s.	30	11	11	8	4.9	...	...
North Yakima	1,071	4	...	...	...	...	60.3	...	88	24	75	29	29	45	44	...	...	...	0.69	...	8	...	nw.	...	...	...	18	3	9	...	...	...
Port Angeles	29	8	48	29.98	30.03	...	55.6	...	82	24	65	34	29	46	31	...	...	...	0.91	− 0.9	5	3,873	s.	36	w.	19	15	8	7	4.2	...	...
Seattle	125	215	250	29.88	30.01	.00	59.6	+ 1.7	80	14	67	40	29	52	27	54	49	73	2.03	+ 0.1	8	5,106	n.	23	s.	19	11	7	12	5.1	...	...
Tacoma	213	113	120	29.78	30.00	− .02	58.8	+ 1.2	81	15	67	37	29	50	29	54	50	75	1.62	− 0.8	7	3,592	n.	24	n.	13	10	10	10	5.7	...	...
Tatoosh Island	86	7	57	29.89	29.99	− .02	54.4	+ 1.4	68	14	59	44	28	50	17	52	50	87	3.12	− 3.0	9	8,922	ne.	43	ne.	23	15	8	7	4.1	...	...
Medford	1,425	4	...	...	...	...	62.0	...	96	23	78	35	28	46	54	...	...	...	0.66	...	8	...	nw.	...	...	...	11	10	9	...	...	...
Portland, Oreg	153	68	106	29.81	29.96	− .07	62.5	+ 1.5	85	23	71	44	29	54	33	55	49	68	3.18	+ 1.3	10	4,082	nw.	25	e.	21	16	3	11	4.4	...	...
Roseburg	510	9	57	29.42	29.97	− .05	61.0	+ 0.5	88	14	73	40	29	49	41	54	49	71	3.36	+ 2.3	9	1,890	n.	21	sw.	5	16	7	7	4.0	...	...
Middle Pacific Coast Region.							**63.4**	**− 0.1**										**64**	**0.77**	**+ 0.2**										**3.5**		
Eureka	62	73	89	29.90	29.96	− .05	56.5	+ 1.6	67	19	62	45	29	51	16	53	52	85	1.52	+ 0.4	10	3,931	sw.	35	n.	20	9	8	13	5.5	...	...
Mount Tamalpais	2,375	11	31	27.47	29.91	− .03	63.0	− 3.1	92	23	70	42	29	56	28	52	42	56	1.26	+ 0.6	4	12,874	nw.	70	nw.	6	20	7	3	2.5	...	...
Point Reyes Light	490	7	18	29.36	29.87	...	56.3	+ 0.2	86	19	61	49	25	52	31	...	...	...	0.16	...	2	13,436	nw.	48	nw.	2	9	10	11	5.9	...	...
Red Bluff	332	50	56	29.50	29.84	− .09	72.1	− 1.8	101	19	85	49	29	60	36	57	43	44	0.66	− 0.1	5	4,498	nw.	24	nw.	19	22	3	5	2.6	...	...
Sacramento	69	106	117	29.78	29.85	− .04	69.7	+ 0.7	100	20	83	47	30	56	41	58	49	56	0.53	+ 0.1	5	5,774	s.	31	sw.	27	23	2	5	2.1	...	...
San Francisco	155	208	243	29.73	29.90	− .04	62.0	+ 2.7	93	19	69	52	24	55	39	56	52	78	0.39	+ 0.1	3	7,975	sw.	42	sw.	13	17	8	5	3.3	...	...
San Jose	141	12	110	29.77	29.92	...	63.9	− 0.8	97	19	78	45	3	50	46	...	...	...	0.25	− 0.1	2	3,847	nw.	20	s.	7	20	6	4	2.6	...	...
South Pacific Coast Region.							**68.1**	**0.0**										**69**	**0.56**	**+ 0.4**										**2.8**		
Fresno	327	89	98	29.49	29.84	− .03	73.2	− 1.1	99	24	87	52	30	59	38	57	44	43	0.29	0.0	3	5,264	nw.	29	nw.	10	24	4	2	1.5	...	...
Los Angeles	338	159	191	29.50	29.86	− .02	68.3	− 1.2	92	12	78	53	14	59	34	60	56	75	1.29	+ 1.2	4	3,673	sw.	18	sw.	9	19	6	5	3.4	...	...
San Diego	87	62	70	29.76	29.85	− .04	66.5	− 0.4	79	24	72	57	7	61	21	62	60	84	0.26	+ 0.2	3	4,555	nw.	20	s.	26	16	11	3	3.8	...	...
San Luis Obispo	201	32	40	29.68	29.90	− .03	64.4	+ 2.9	99	23	77	48	15	52	49	55	50	73	0.42	0.0	3	2,989	nw.	18	ne.	12	25	3	2	2.6	...	...
West Indies.																																
San Juan, P. R	82	8	54	29.85	29.93	...	79.8	...	91	23	85	72	4	74	17	...	...	...	5.63	− 1.2	17	6,633	s.	32	e.	3	3	20	7	6.0	...	...
Panama Canal.																																
Balboa Heights	118	7	97	29.71	29.83	00	79.4	− 0.4	90	6	85	71	27	74	18	75	74	87	10.84	+ 3.0	21	4,090	nw.	22	s.	13	0	14	16	7.5	...	...
Colon	36	15	97	29.79	29.83	− .01	80.6	+ 0.8	90	12	86	73	4	75	14	76	75	84	11.74	− 0.9	20	4,928	se.	27	n.	7	1	13	16	7.7	...	...

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during September, 1919, at all stations furnished with self-registering gages.*

Stations.	Date.	Total duration. From—	Total duration. To—	Total amount of precipitation.	Excessive rate. Began—	Excessive rate. Ended—	Amount before excessive rate began.	5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Abilene, Tex.	19			0.63														0.37			
Albany, N. Y.	22			0.73														0.52			
Alpena, Mich.	15			0.28														0.16			
Amarillo, Tex.	16-17	6:10 p. m.	5:40 a. m.	1.48	1:30 a. m.	2:06 a. m.	0.58	0.05	0.10	0.28	0.34	0.48	0.53	0.66	0.68						
Anniston, Ala.	19	5:00 p. m.	5:55 p. m.	0.53	5:13 p. m.	5:36 p. m.	0.01	0.06	0.11	0.18	0.38	0.51									
Asheville, N. C.	23			0.19														0.19			
Atlanta, Ga.	20			0.41														0.39			
Atlantic City, N. J.	10			0.72														0.65			
Augusta, Ga.	22			0.06														0.06			
Baker, Oreg.	11			0.09														0.07			
Baltimore, Md.	22			0.75														0.52			
Bentonville, Ark.	21-22			1.34														0.44			
Binghamton, N. Y.	9			0.23														0.15			
Birmingham, Ala.	12	D. N. a. m.	D. N. a. m.	1.04	12:42 a. m.	1:16 a. m.	0.03	0.18	0.38	0.52	0.66	0.75	0.83	0.90							
Bismarck, N. Dak.	9			0.14														0.09			
Block Island, R. I.	1			0.47														0.47			
Boise, Idaho	30			0.34														0.23			
Boston, Mass.	3			2.94														0.67			
Buffalo, N. Y.	11			0.42														0.38			
Burlington, Vt.	8	3:25 a. m.	4:40 a. m.	0.52	3:56 a. m.	4:21 a. m.	0.01	0.06	0.14	0.31	0.39	0.50									
Cairo, Ill.	20			0.82														0.44			
Canton, N. Y.	8			2.41														0.89			
Charles City, Iowa	9			1.00														0.66			
Charleston, S. C.	2			0.55														0.47			
Charlotte, N. C.	11			0.48														0.43			
Chattanooga, Tenn.	22			0.03														0.03			
Cheyenne, Wyo.	20-21			0.60														*			
Chicago, Ill.	10			0.74														0.59			
Cincinnati, Ohio	22	6:32 a. m.	1:10 p. m.	1.74	6:56 a. m.	7:55 a. m.	0.07	0.05	0.18	0.32	0.25	0.42	0.56	0.68	0.79	0.89	0.95	1.07			
	30	3:08 p. m.	3:44 p. m.	0.60	3:17 p. m.	3:35 p. m.	0.01	0.11	0.36	0.56	0.59										
Cleveland, Ohio	11			0.35														0.27			
Columbia, Mo.	18	6:11 p. m.	6:49 p. m.	0.69	6:20 p. m.	6:41 p. m.	0.01	0.24	0.34	0.43	0.63	0.67									
Columbia, S. C.	11			0.08														0.08			
Columbus, Ohio	21			0.38														0.23			
Concord, N. H.	8-9			0.86														0.45			
Concordia, Kans.	18			1.61														0.64			
Corpus Christi, Tex.	17			0.76														0.40			
Dallas, Tex.	19	3:16 p. m.	8:35 p. m.	0.91	3:59 p. m.	4:27 p. m.	0.09	0.12	0.23	0.34	0.40	0.47	0.51								
	21-22	7:10 p. m.	5:45 a. m.	2.50	9:25 p. m.	10:26 p. m.	0.01	0.06	0.13	0.16	0.25	0.34	0.42	0.64	0.91	1.18	1.48	1.75	1.82		
Davenport, Iowa	29-30	9:45 p. m.	9:35 a. m.	3.48	4:28 a. m.	5:22 a. m.	0.77	0.20	0.52	0.74	0.93	1.16	1.54	1.99	2.11	2.20	2.28	2.36			
Dayton, Ohio	21			0.72														0.40			
Del Rio, Tex.	15	6:45 p. m.	9:40 p. m.	1.06	7:21 p. m.	7:38 p. m.	0.06	0.10	0.26	0.54	0.69										
	22-23	4:00 a. m.	12:00 mid.	6.43	5:24 a. m.	7:02 a. m.	0.12	0.14	0.25	0.36	0.52	0.60	0.71	0.79	0.89	1.03	1.18	1.53	2.72	3.16	
					7:52 a. m.	8:59 a. m.	3.32	0.06	0.13	0.18	0.31	0.41	0.51	0.62	0.70	0.73	0.78	0.91	1.00		
Denver, Colo.	13			0.35														0.24			
Des Moines, Iowa	18	9:55 a. m.	4:20 p. m.	1.16	1:28 p. m.	2:03 p. m.	0.45	0.06	0.12	0.20	0.37	0.46	0.53	0.61							
		7:43 p. m.	D. N. p. m.	1.15	8:13 p. m.	8:46 p. m.	0.01	0.13	0.22	0.37	0.53	0.58	0.65	0.70							
	20-21	8:05 p. m.	D. N. a. m.	1.76	8:12 p. m.	8:57 p. m.	0.02	0.12	0.28	0.48	0.76	0.83	0.93	1.01	1.13	1.24					
Detroit, Mich.	20	6:35 p. m.	8:55 p. m.	1.16	6:53 p. m.	7:15 p. m.	0.01	0.09	0.14	0.41	0.65	0.69									
	21	12:13 p. m.	4:55 p. m.	1.71	3:20 p. m.	4:17 p. m.	0.64	0.07	0.21	0.40	0.59	0.66	0.77	0.80	0.81	0.83	0.89	1.05			
Devils Lake, N. Dak.	9			0.77														0.37			
Dodge City, Kans.	17			0.99														0.20			
Drexel, Nebr.	18			2.36														0.47			
Dubuque, Iowa	19			1.47														0.73			
Duluth, Minn.	6			0.37														0.18			
Eastport, Me.	3			1.60														0.37			
Elkins, W. Va.	22			1.32														0.45			
Ellendale, N. Dak.	4			0.13*														0.05			
El Paso, Tex.	12			0.25														0.22			
Erie, Pa.	21			0.56														0.22			
Escanaba, Mich.	29			0.60														0.36			
Eureka, Calif.	30			0.59														0.15			
Evansville, Ind.	21	12:15 p. m.	4:45 p. m.	1.84	2:59 p. m.	3:40 p. m.	0.50	0.22	†0.32	†0.44	†0.65	†0.87	†0.95	†1.18	†1.32	†1.33					
Flagstaff, Ariz.	27			0.85														*			
Fort Smith, Ark.	21			0.43														0.33			
Fort Wayne, Ind.	21			1.84														0.47			
Fort Worth, Tex.	19	2:19 p. m.	7:41 p. m.	3.18	2:32 p. m.	3:41 p. m.	0.03	0.06	0.11	0.27	0.44	0.67	0.88	1.35	1.73	2.08	2.39	2.68	2.81		
Fresno, Calif.	29			0.24														0.07			
Galveston, Tex.	5-6	8:35 p. m.	6:30 a. m.	1.79	10:54 p. m.	11:52 p. m.	0.11	0.12	0.18	0.28	0.54	0.80	0.93	0.96	0.98	1.04	1.09	1.32			
Grand Haven, Mich.	20	4:24 p. m.	8:20 p. m.	2.29	6:09 p. m.	6:54 p. m.	0.32	0.08	0.18	0.26	0.46	0.70	0.89	0.97	1.12	1.46					
Grand Junction, Colo.	2			0.56														0.37			
Grand Rapids, Mich.	20	10:20 a. m.	2:50 p. m.	1.20	1:51 p. m.	2:26 p. m.	0.38	0.10	0.21	0.36	0.54	0.62	0.71	0.77							
Green Bay, Wis.	20			0.71														0.45			
Greenville, S. C.	21			0.04														0.04			
Hannibal, Mo.	18	7:20 p. m.	9:10 p. m.	0.98	8:11 p. m.	8:48 p. m.	0.07	0.21	0.26	0.27	0.37	0.49	0.67	0.82	0.88						
Harrisburg, Pa.	11			0.48														0.29			
Hartford, Conn.	3			1.77														0.44			
Hatteras, N. C.	1	D. N. a. m.	7:28 a. m.	1.00	5:15 a. m.	5:46 a. m.	0.03	0.16	0.27	0.55	0.71	0.78	0.85	0.89							
Havre, Mont.	20-21			0.12														0.08			
Helena, Mont.	8			0.27														0.16			
Houghton, Mich.	18			0.24														0.19			
Houston, Tex.	7	12:30 p. m.	1:05 p. m.	0.93	12:34 p. m.	12:54 p. m.	0.01	0.16	0.41	0.66	0.89										
	14	6:42 p. m.	10:15 p. m.	2.70	6:55 p. m.	8:25 p. m.	0.04	0.21	0.32	0.44	0.50	0.58	0.69	0.80	0.82	0.82	0.87	1.23	1.98	2.19	
	15	7:26 a. m.	12:45 p. m.	2.80	11:14 a. m.	12:19 p. m.	1.29	0.11	0.22	0.31	0.42	0.47	0.50	0.60	0.75	0.91	1.05	1.25	1.51		
Huron, S. Dak.	12			0.23														0.23			
Independence, Calif.	27			T.														T.			
Indianapolis, Ind.	21			1.35														0.68			
Iola, Kans.	10-11	8:10 p. m.	D. N. a. m.	0.95	8:31 p. m.	8:51 p. m.	0.07	0.07	0.22	0.41	0.52										
Jacksonville, Fla.	1	4:15 p. m.	7:18 p. m.	0.73	4:25 p. m.	4:51 p. m.	0.01	0.25	0.34	0.36	0.41	0.56	0.59								
	13-14	11:27 p. m.	D. N. a. m.	0.85	11:51 p. m.	12:11 a. m.	0.06	0.09	0.31	0.60	0.75										
Kalispell, Mont.	7			0.13														0.12			
Kansas City, Mo.	21	2:25 a. m.	8:20 a. m.	1.72	6:19 a. m.	6:41 a. m.	0.83	0.07	0.20	0.47	0.72	0.78									
Keokuk, Iowa	18	2:25 p. m.	4:00 p. m.	0.84	2:43 p. m.	3:02 p. m.	0.03	0.17	0.39	0.52	0.61										
	21	D. N. a. m.	7:35 a. m.	1.19	12:55 a. m.	1:25 a. m.	0.23	0.15	0.17	0.31	0.46	0.62	0.76								
	28	D. N. a. m.	7:02 a. m.	1.44	6:08 a. m.	6:43 a. m.	0.30	0.05	0.25	0.28	0.34	0.57	0.92	1.12							
Key West, Fla.	9-10			11.95														*			
Knoxville, Tenn.	22			0.34														0.34			
La Crosse, Wis.	9			1.00														0.64			

* Self-register not in use. † Record partly estimated.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during September, 1919, at all stations furnished with self-registering gages*—Continued.

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.													
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Lander, Wyo.	20-21			0.61														*			
Lansing, Mich.	20			0.43														0.38			
Lewiston, Idaho	6			0.32														0.17			
Lexington, Ky.	21			0.60														0.36			
Lincoln, Nebr.	16	2:43 p. m.	3:45 p. m.	0.76	3:05 p. m.	3:21 p. m.	0.02	0.30	0.50	0.63	0.67										
Little Rock, Ark.	21	4:48 p. m.	6:40 p. m.	0.70	5:13 p. m.	5:35 p. m.	0.02	0.10	0.23	0.38	0.51	0.57									
Los Angeles, Calif.	27			0.68														0.26			
Louisville, Ky.	19	10:40 a. m.	11:35 a. m.	1.01	11:00 a. m.	11:20 a. m.	T.	0.21	0.59	0.77	0.96										
	21	1:15 p. m.	6:35 p. m.	1.11	4:25 p. m.	5:01 p. m.	0.22	0.11	0.22	0.29	0.35	0.39	0.48	0.61	0.79						
Ludington, Mich.	21	12:25 a. m.	D. N. a. m.	0.86	12:26 a. m.	1:00 a. m.	0.01	0.11	0.19	0.20	0.37	0.47	0.53	0.57							
	28-29	D. N. p. m.	D. N. a. m.	1.58	12:28 a. m.	1:00 a. m.	0.61	0.08	0.24	0.27	0.51	0.68	0.74	0.80							
Lynchburg, Va.	22			0.32														0.28			
Macon, Ga.	12			0.46														0.46			
Madison, Wis.	20-21	9:22 p. m.	4:00 a. m.	1.91	10:34 p. m.	11:06 p. m.	0.44	0.11	0.47	0.72	0.89	0.96	1.04	1.09							
	28-29	6:10 p. m.	D. N. a. m.	1.26	10:38 p. m.	11:02 p. m.	0.08	0.12	0.24	0.41	0.57	0.67									
Marquette, Mich.	14			0.58														0.30			
Memphis, Tenn.	21-22			1.21														0.48			
Meridian, Miss.	20			0.21														0.11			
Miami, Fla.	1-2	D. N. p. m.	D. N. a. m.	1.65	10:45 p. m.	11:38 p. m.	0.02	0.16	0.24	0.31	0.41	0.56	0.81	1.02	1.17	1.32	1.44	1.58			
	3	D. N. p. m.	D. N. p. m.	0.67	10:12 p. m.	10:30 p. m.	0.01	0.22	0.32	0.45	0.66										
Milwaukee, Wis.	20	2:54 p. m.	3:35 p. m.	0.84	3:04 p. m.	3:23 p. m.	0.04	0.11	0.33	0.63	0.77										
Minneapolis, Minn.	17			0.42														0.27			
Mobile, Ala.	7			0.44														0.26			
Modena, Utah	26			0.87														0.61			
Montgomery, Ala.	23			0.07														0.07			
Moorhead, Minn.	13			0.52														0.51			
Mount Tamalpais, Calif.	29			0.62														0.51			
Nantucket, Mass.	23			1.13														0.65			
Nashville, Tenn.	21-22			1.33														0.69			
New Haven, Conn.	2-3	5:45 a. m.	7:05 a. m.	3.44	10:21 p. m.	11:34 p. m.	0.66	0.14	0.34	0.46	0.52	0.59	0.15	0.74	0.91	1.12	1.27	1.59	1.87		
	11-12	9:01 p. m.	D. N. a. m.	1.10	10:09 p. m.	10:35 p. m.	T.	0.09	0.19	0.34	0.58	0.88	0.92								
New Orleans, La.	7	10:45 a. m.	11:41 a. m.	0.82	11:02 a. m.	11:29 a. m.	0.02	0.08	0.30	0.62	0.68	0.77	0.80								
New York	22-23			2.27														0.61			
Norfolk, Va.	23			0.66														0.25			
Northfield, Vt.																					
North Head, Wash.	30			0.60														0.39			
North Platte, Nebr.	12			0.72														0.61			
Oklahoma, Okla.	18			0.39														0.32			
Omaha, Nebr.	18	5:05 a. m.	3:25 p. m.	3.49	10:35 a. m.	12:03 p. m.	1.61	0.06	0.12	0.21	0.28	0.35	0.43	0.51	0.55	0.61	0.69	0.84	1.17	1.34	
	29	6:10 p. m.	8:55 p. m.	0.83	6:26 p. m.	6:40 p. m.	0.02	0.24	0.56	0.64											
Oswego, N. Y.	2	4:38 a. m.	7:12 a. m.	0.54	4:38 a. m.	5:01 a. m.	0.00	0.08	0.22	0.33	0.47	0.51									
Palestine, Tex.	20	2:19 p. m.	5:10 p. m.	0.65	2:23 p. m.	2:38 p. m.	0.03	0.20	0.42	0.55											
	22	4:00 a. m.	2:20 p. m.	3.21	4:17 a. m.	5:07 a. m.	0.02	0.09	0.16	0.17	0.22	0.27	0.32	0.41	0.49	0.56	0.72				
					5:07 a. m.	5:57 a. m.		0.90	1.02	1.24	1.43	1.51	1.65	1.76	1.86	1.95	2.03				
Parkersburg, W. Va.	21			0.58														0.42			
Pensacola, Fla.	12-13			0.16														0.15			
Peoria, Ill.	18-19			1.38														0.37			
Philadelphia, Pa.	22			0.83														0.51			
Phoenix, Ariz.	26			1.20														0.76			
Pierre, S. Dak.	10	8:30 a. m.	10:00 a. m.	1.20	9:02 a. m.	9:42 a. m.	0.04	0.06	0.19	0.33	0.56	0.57	0.61	0.91	1.13						
Pittsburgh, Pa.	10			0.46														0.45			
Pocatello, Idaho	2			0.82														0.46			
Point Reyes Light, Calif.	7			0.15														0.03			
Port Angeles, Wash.	30			0.23														0.15			
Port Huron, Mich.	20			1.17														0.75			
Portland, Me.	8			0.69														0.30			
Portland, Oreg.	4			0.38														0.21			
Providence, R. I.	11			0.87														0.50			
Pueblo, Colo.	9-10	10:00 p. m.	D. N. a. m.	1.49	11:17 p. m.	12:08 a. m.	0.05	0.09	0.38	0.49	0.63	0.67	0.82	0.91	0.98	1.04	1.10	1.16			
Raleigh, N. C.	11			0.21														0.17			
Rapid City, S. Dak.	1			0.88														0.36			
Reading, Pa.	22			0.83														0.51			
Red Bluff, Calif.	7			0.28														0.12			
Reno, Nev.	29			0.37														0.11			
Richmond, Va.	10			0.41														0.40			
Rochester, N. Y.	20			0.66														0.54			
Roseburg, Oreg.	8			1.02														0.51			
Roswell, N. Mex.	15-16	7:42 a. m.	8:12 a. m.	3.52	3:35 p. m.	3:48 p. m.	0.70	0.18	0.51	0.61											
Sacramento, Cal.	7			0.39														0.12			
Saginaw, Mich.	29			0.70														0.30			
St. Joseph, Mo.	20-21	D. N. p. m.	8:40 a. m.	1.77	4:46 a. m.	5:20 a. m.	0.85	0.05	0.13	0.27	0.44	0.60	0.69	0.73							
	28	5:47 p. m.	D. N. p. m.	1.05	7:35 p. m.	8:03 p. m.	0.39	0.07	0.22	0.40	0.49	0.61	0.65								
	21	6:55 a. m.	1:45 p. m.	1.25	7:36 a. m.	8:18 a. m.	T.	0.12	0.14	0.21	0.24	0.43	0.50	0.61	0.68	0.70					
St. Louis, Mo.	28	2:30 p. m.	8:45 p. m.	3.73	6:06 p. m.	6:56 p. m.	0.12	0.14	0.42	0.70	0.90	1.09	1.23	1.38	1.62	1.88	1.99				
					6:56 p. m.	7:46 p. m.		2.16	2.40	2.44	2.47	2.50	2.50	2.52	2.57	2.65	2.75				
					7:46 p. m.	8:30 p. m.		2.82	2.83	2.87	2.96	3.11	3.33	3.46	3.54	3.59					
St. Paul, Minn.	28			0.49														0.28			
Salt Lake City, Utah	3			0.52														0.33			
San Antonio, Tex.	15			2.50														0.72			
San Diego, Cal.	30			0.12														0.11			
Sand Key, Fla.																					
Sandusky, Ohio	10			0.55														0.47			
Sandy Hook, N. J.	3			0.59														0.46			
San Francisco, Cal.	29			0.20														0.09			
San Jose, Cal.	28			0.24														*			
San Luis Obispo, Cal.	28			0.25														0.14			
Santa Fe, N. Mex.	13			0.34														0.34			
Sault Ste. Marie, Mich.	20			0.70														0.61			
Savannah, Ga.	12			1.11														0.54			
Scranton, Pa.	22			0.91														0.29			
Seattle, Wash.	11			1.32														0.22			
Sheridan, Wyo.	1			0.58														0.49			
Shreveport, La.	6	3:30 p. m.	4:40 p. m.	0.88	3:35 p. m.	3:53 p. m.	0.03	0.30	0.59	0.73	0.81										
Sioux City, Iowa	3			0.95														0.44			
Spokane, Wash.	4			0.12														0.12			
Springfield, Ill.	21			1.04														0.59			
Springfield, Mo.	21	6.24 a. m.	7:52 a. m.	0.90	6.24 a. m.	7:04 a. m.	0.00	0.10	0.20	0.26	0.49	0.59	0.65	0.72	0.80						
Syracuse, N. Y.	12			0.63														0.43			
Tacoma, Wash.	11			0.52														0.14			

* Self-register not in use.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during September, 1919, at all stations furnished with self-registering gages*—Continued.

Stations.	Date.	Total duration. From—	Total duration. To—	Total amount of precipitation.	Excessive rate. Began—	Excessive rate. Ended—	Amount before excessive rate began.	5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Tampa, Fla.	6	3:55 p. m.	5:00 p. m.	2.03	3:59 p. m.	4:21 p. m.	0.01	0.40	1.36	1.36	1.80	1.95									
Tampa, Fla.	16	5:15 p. m.	D. N. p. m.	2.05	5:17 p. m.	6:05 p. m.	0.01	0.20	0.45	0.68	0.95	1.19	1.36	1.50	1.67	1.75	1.80				
Tampa, Fla.	20	4:36 p. m.	5:55 p. m.	1.68	4:39 p. m.	5:08 p. m.	0.01	0.37	0.85	1.20	1.38	1.47	1.53								
Tatoosh Island, Wash.	30			1.64														0.44			
Taylor, Tex.	14-15	1:39 p. m.	6:30 a. m.	3.01	2:22 a. m.	3:33 a. m.	0.86	0.06	0.13	0.15	0.20	0.34	0.47	0.62	0.88	1.11	1.29	1.71	2.11		
Terre Haute, Ind.	10	5:05 p. m.	6:15 p. m.	0.79	5:14 p. m.	5:37 p. m.	0.01	0.10	0.29	0.56	0.70	0.75									
Thomasville, Ga.	10			0.11														0.11			
Toledo, Ohio	11			0.21														0.21			
Tonopah, Nev.	27			0.20														0.20			
Topeka, Kans.	21	D. N. a. m.	D. N. a. m.	1.64	4:32 a. m.	5:09 a. m.	0.12	0.17	0.32	0.63	0.86	1.17	1.26	1.36	1.41						
Trenton, N. J.	11	10:10 p. m.	D. N. p. m.	0.87	10:12 p. m.	10:22 p. m.	0.01	0.35	0.72	0.76											
Valentine, Nebr.	8			0.57														0.49			
Vicksburg, Miss.	22			0.29														0.29			
Walla Walla, Wash.	7			0.42														0.31			
Washington, D. C.	11	7:00 p. m.	7:45 p. m.	0.66	7:10 p. m.	7:23 p. m.	0.01	0.22	0.44	0.59											
Wausau, Wis.	28-29			1.02														0.33			
Wichita, Kans.	18			0.22														0.15			
Williston, N. Dak.	6-7	9:22 p. m.	D. N. a. m.	0.93	9:38 p. m.	9:50 p. m.	0.06	0.31	0.55	0.60											
Wilmington, N. C.	2			0.93														0.35			
Winnemucca, Nev.	30			0.21														0.12			
Wytheville, Va.	21			0.62														0.38			
Yankton, S. Dak.	9	12:30 a. m.	5:10 a. m.	1.04	12:59 a. m.	1:24 a. m.	0.03	0.11	0.26	0.37	0.45	0.53									
Yellowstone Park, Wyo.	27-28			0.78														*			

* Self-register not in use.

TABLE III.—*Data furnished by the Canadian meteorological service, September 1919.*

Stations.	Altitude above mean sea level Jan. 1, 1919.	Pressure. Station reduced to mean of 24 hours.	Pressure. Sea level reduced to mean of 24 hours.	Pressure. Departure from normal.	Temperature. Mean max. + mean min. ÷ 2.	Temperature. Departure from normal.	Temperature. Mean maximum.	Temperature. Mean minimum.	Temperature. Highest.	Temperature. Lowest.	Precipitation. Total.	Precipitation. Departure from normal.	Precipitation. Total snowfall.
	Feet.	*Inches.*	*Inches.*	*Inches.*	° F.	° F.	° F.	° F.	° F.	° F.	*Inches.*	*Inches.*	*Inches.*
St. Johns, N. F.	125	29.86	30.00	−0.03	54.9	+0.9	63.2	46.6	74	34	4.70	+0.99	
Sydney, C. B. I.	48	29.97	29.91	− .10	58.0	+1.5	66.3	49.6	76	36	4.56	+1.28	
Halifax, N. S.	88	29.90	30.00	− .04	57.8	+0.2	65.3	50.3	73	37	5.08	+1.37	
Yarmouth, N. S.	65	29.92	29.99	− .06	56.4	+0.3	63.4	49.3	79	36	3.44	−0.01	
Charlottetown, P. E. I.	38	29.93	29.97	− .04	57.5	+0.2	63.8	51.3	75	35	5.11	+1.71	
Chatham, N. B.	28	29.96			56.6	+1.2	65.3	47.9	78	32	3.81	+1.10	
Father Point, Que.	20	29.91	29.93	− .05	50.3	−0.1	58.5	42.2	82	31	2.21	−0.92	
Quebec, Que.	296	29.65	29.98	− .03	54.8	−0.3	63.0	46.6	78	32	3.39	−0.28	
Montreal, Que.	187	29.76	29.96	− .08	58.2	−0.2	65.8	50.6	80	39	3.92	+0.62	
Stonecliffe, Ont.	489	29.36	29.97	− .06	49.6	−6.1	68.1	31.2	84	20	5.57	+2.29	
Ottawa, Ont.	236	29.71	29.97	− .07	59.2	+1.8	70.0	48.4	84	36	2.68	−0.01	
Kingston, Ont.	285	29.68	29.99	− .05	63.7	+3.7	72.2	55.2	85	42	2.36	−0.44	
Toronto, Ont.	379	29.59	29.99	− .07	63.4	+4.4	73.9	53.0	95	39	1.91	−1.34	
Cochrane, Ont.	930				49.7		58.2	42.1	72	28	3.20		T.
White River, Ont.	1,244	28.61	29.93	− .05	49.3	−1.0	59.6	39.1	76	22	5.73	+2.96	
Port Stanley, Ont.	592	29.38	30.02	− .04	61.2	+1.7	69.4	53.0	78	36	3.93	+1.20	
Southampton, Ont.	656	29.28			61.9	+4.4	70.7	53.1	86	38	1.98	−0.96	T.
Parry Sound, Ont.	688	29.29	29.97	− .06	59.9	+3.9	69.1	50.8	86	35	3.32	−0.35	
Port Arthur, Ont.	644	29.26	29.97	− .01	52.9	+0.7	62.3	43.6	73	31	3.00	−0.48	
Winnipeg, Man.	760	29.10	29.92	− .02	56.0	+3.5	66.3	45.8	80	26	3.24	+1.21	
Minnedosa, Man.	1,690	28.13	29.92	− .02	54.2	+3.7	65.4	43.0	82	26	1.18	−0.18	1.2
Le Pas, Man.	860				51.6		62.3	41.0	80	28			
Qu'Appelle, Sask.	2,115	27.70	29.93	+ .01	53.8	+2.7	66.4	41.3	87	19	1.06	−0.27	0.8
Medicine Hat, Alb.	2,144	27.63	29.87	− .05	58.8	+3.8	73.1	44.5	90	26	1.12	−0.06	
Moose Jaw, Sask.	1,759				57.4		71.8	43.0	92	25	0.23		T.
Swift Current, Sask.	2,392	27.35	29.94	+ .02	56.3	+3.2	70.1	42.5	86	25	1.06	−0.16	
Calgary, Alb.	3,428	26.43	29.98	+ .06	52.5	+2.7	66.6	38.4	79	22	1.35	−0.01	−0.2
Banff, Alb.	4,521	25.40	29.95	+ .02	48.3	+2.5	62.4	34.3	72	13	0.62	−1.05	−0.5
Edmonton, Alb.	2,150	27.60	29.86	− .04	52.7	+3.4	65.5	40.0	76	20	1.40	+0.07	−0.2
Prince Albert, Sask.	1,450	28.38	29.95	+ .05	52.5	+4.1	62.9	42.2	78	28	3.27	+1.99	
Battleford, Sask.	1,592	28.17	29.90	.00	54.4	+2.6	66.9	42.0	82	24	1.84	+0.59	
Kamloops, B. C.	1,262	28.74			60.4	+3.0	73.4	47.4	84	31	0.59	−0.26	
Victoria, B. C.	230	29.74	29.99	− .02	57.6	+2.8	61.9	50.4	81	42	1.35	−0.81	
Barkerville, B. C.	4,180	25.74			46.0	−0.7	56.3	35.6	67	17	1.73	−1.18	
Triangle Island, B. C.	680												
Prince Rupert, B. C.	170												
Hamilton, Ber.	151	29.87	30.03	− .04	77.8	+0.4	83.2	72.5	85	70	5.72	−0.79	

SEISMOLOGY.

W. J. HUMPHREYS, Professor in Charge.

[Dated: Weather Bureau, Washington, D. C., Nov. 3, 1919.]

TABLE 1.—*Noninstrumental earthquake reports, September, 1919.*

Day.	Approximate time, Greenwich civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
		CALIFORNIA.								
	H. m.		° ′	° ′			*Sec.*			
Sept. 4.	20 16	Berkeley	37 51	121 18	3	1	1	None	Felt by many	E. F. Davis.
	20 16	San Francisco	37 48	122 26	3	1		do	Felt by several	U. S. Weather Bureau.
	20 17	Oakland	37 48	122 15	3	1	3	Rattling	Felt by mechanics at work in building.	Chas. Burckhalter.
12	17 07	Eureka	40 48	124 10	4	2	(1)	Faint rumbling	Felt by many	U. S. Weather Bureau.
	19 30	do	40 48	124 10	5	2	1	do	do	Do.
15	14 07	do	40 48	124 10	6	1	2	Building creaked	do	Do.
	16 08	do	40 48	124 10	4	1	5	do	do	Do.
	19 16	do	40 48	124 10	4	2	2	do	do	Do.
30	4 29	Calexico	34 41	115 30	3	1	15	Faint rumbling	do	H. M. Rouse.
	5 04	do	34 41	115 30	2	1	10	None	Felt by several	Do.
	5 06	do	34 41	115 30	3	1	30	Faint rumbling	do	Do.
	7 40	Amos	33 00	115 07	4	2	2	do	do	G. T. Hartsfield.
	8 38	Calexico	34 41	115 30	4	1	45	Loud rumbling	Felt by many	H. M. Rouse.

[1] Fraction of second.

TABLE 2.—*Instrumental seismological reports, September, 1919.*

(Time used: Mean Greenwich, midnight to midnight. Nomenclature: International.)

[For significance of symbols see REVIEW for January, 1919, p. 59.]

Alabama. *Mobile. Spring Hill College.* Earthquake Station. Cyril Ruhlmann, S. J.

Lat., 30° 41′ 44″ N.; long., 88° 08′ 46″ W. Elevation, 60 meters.

Instrument: Wiechert 80 kg.; astatic, horizontal pendulum.

(Report for September, 1919, not received.)

Alaska. *Sitka. Magnetic Observatory.* U. S. Coast and Geodetic Survey. F. P. Ulrich.

Lat., 57° 03′ 00″ N.; long., 135° 30′ 06″ W. Elevation, 15.2 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants.. E: V 10, T_0 17; N: V 10, T_0 15

No earthquake recorded during September, 1919.

Arizona. *Tucson. Magnetic Observatory.* U. S. Coast and Geodetic Survey. Wm. H. Cullum.

Lat., 32° 14′ 48″ N.; long., 110° 50′ 06″ W. Elevation, 769.6 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants.. E: V 10, T_0 15; N: V 10, T_0 18

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Sept. 11		P_E	21 32 05					Not in operation during September.
		M_E	21 32 28		40			
		F_E	21 36 13	4				
15		eP_E	17 36 15					Probably local.
		L_E	17 37 11					
		M_E	17 38 30		20			
		C_E	17 40 ..	4				
		F_E	17 50 ..					
19		P_E	3 27 30	5				Probably local.
		eL_E	3 28 59					
		M_E	3 30 ..	9	60			
		F_E	3 33 ..	8				
30		iP_E	7 38 28	1				Local.
		S_E	7 39 06					
		M_E	7 39 55	12	280			
		C_E	7 44 ..					
		F_E	7 56 ..	4				

California. *Berkeley. University of California.*

Lat., 37° 52′ 16″ N.; long., 122° 15′ 37″ W. Elevation, 85.4 meters.

(*See* Bulletin of the Seismographic Stations, University of California.)

California. *Mount Hamilton. Lick Observatory.*

Lat., 37° 20′ 24″ N.; long., 121° 38′ 34″ W. Elevation, 1,281.7 meters.

(*See* Bulletin of the Seismographic Stations, University of California.)

California. *Point Loma. Raja Yoga Academy.* F. J. Dick.

Lat., 32° 43′ 03″ N.; long., 117° 15′ 10″ W. Elevation, 91.4 meters.

Instrument: Two-component, C. D. West seismoscope.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			H. m. s.	*Sec.*	μ	μ	*Km.*	
Sept. 30			8 00 ca		400	600		Light shock.

Colorado. *Denver. Sacred Heart College.* Earthquake Station. A. W. Forstall, S. J.

Lat., 39° 40′ 36″ N.; long., 104° 56′ 54″ W. Elevation, 1,655 meters.

Instrument: Wiechert 80 kg., astatic, horizontal pendulum.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
15		P	16 33 ..					Heavy machinery in motion nearby during first portion of record.
		S	(?)					
		L	16 38 30	4-5	*4,500	*4,500		
		M_N	16 38 ..			*4,500		
		M_E	16 39 ..		*6,500			
		C	16 40 ..					
		F	16 40 30					
20								Waves at intervals during the day.

* Trace amplitude.

TABLE II.—*Instrumental seismological reports, September, 1919*—Continued.

District of Columbia. *Washington. Georgetown University.* F. A. Tondorf, S. J.

Lat., 38° 54′ 25″ N.; long., 77° 04′ 24″ W. Elevation, 42.4 meters. Subsoil: Decayed diorite.

Instruments: Wiechert 200 kg. astatic horizontal pendulum, 80 kg. vertical.

Instrumental constants..	V	T_0	ε
E	165	5.4	0
N	143	5.2	0
Z	*80*	*3.0*	*0*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			H. m. s.	*Sec.*	μ	μ	*Km.*	
Sept. 1		L_N	20 06 ..	22				Heavy microseism.
		F	20 10 ..					
6		iP_N	1 45 56					
		eP_N	1 45 56					
		M_E	1 46 12	(†)		500		
		M_N	1 46 14	(†)	300			
		F	1 49 ..					
6		eP_N	9 34 43					
		eP_E	9 34 48					
		iS	9 38 48					
		eL	9 40 42	14				
		L_E	9 41 50	14				
		L	9 42 ..	10				
		F	10 37 ..					
13		e_E	12 28 58					Heavy microseisms difficult to read.
		i_E	12 36 46 to 12 41 37					
		L	12 54 46	17				
		F	13 20 ..					
15		eP?	17 37 24					Heavy microseisms.
		S_E	17 47 57					
		S_N	17 47 59					
		F	18 25 ..					
26		e_E	10 26 41					Very heavy microseisms.
		e_N	10 27 19					F lost in micros.
27		eL_E?	3 48 41	8				Very heavy microseisms.
		L_E	3 52 ..	27				N-S does not show.
		F	4 00 ..					
27		e_E	11 33 48					Very heavy microseisms.
		e_N	11 34 ..					
		F	11 43 ..					
			Vertical.					
15		*iP*	*17 37 27*					
		S	*17 48 27*					
		F	*18 13 ..*					

† Less than ¼ sec.

District of Columbia. *Washington. U. S. Weather Bureau.*

Lat., 38° 54′ 12″ N.; long., 77° 03′ 03″ W. Elevation, 21 meters.

Instrument: Marvin (vertical pendulum), undamped. Mechanical registration.

Instrumental constants.. V 110, T_0 6.4

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			H. m. s.	*Sec.*	μ	μ	*Km.*	
Sept. 1		eL	20 07 ca	20				Clock stopped.
		F	20 15 ca					
5		P	19 07 22				2,600	
		S	19 11 35					
		eL	19 17 30					
		F	19 25 ..					
6		P	1 46 00			*375		Reported near Front Royal, Va.
		S	1 46 08					
		M_E	1 46 16					
		F	1 47 20					
6		P	9 34 50ca					Clock not registering.
		S	9 38 50ca					
		L	9 42 ca					
		L	9 44 50ca					
		F	10 40 ..					
13		P	12 28 57				6,160	
		S	12 36 42					
		L	12 54 ..	16				
		F	13 10 ..					

[1] Dr. T. L. Watson, of the University of Virginia, is preparing for publication elsewhere a report of this earthquake, which occurred at the same place as that of April —, 1918.

District of Columbia. *Washington. U. S. Weather Bureau*—Contd.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
Sept. 15		P	17 37 26					
		S	17 42 04					
		M_N	17 48 30			*300		
		L	17 51 50	12				
		F	18 10 ca					
15		e	17 49 30					
		F	18 00 ..					
26		e	9 27 10					
		F	9 40 ca					
26		e	20 00 50					
27		e	3 39 55					Very feeble.
		F	4 05 ..					
27		e	11 33 25					
		F	11 42					
30		e	7 54 30					
		L?	7 55 40					
		F	8 15 ..					

Hawaii. *Honolulu. Magnetic Observatory.* U. S. Coast and Geodetic Survey. Frank Neumann.

Lat., 21° 19′ 12″ N.; long., 158° 03′ 48″ W. Elevation, 15.2 meters.

Instrument: Milne seismograph of the Seismological Committee of the British Association

Instrumental constant T_0 18.4. Sensitivity, 0.40″.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			H. m. s.	*Sec.*	μ	μ	*Km.*	
Sept. 12		eL	14 17 ..					Preceded and followed by several hours of tremors.
		M	14 22 30	17		*200		
		C	14 25 00					
13		L	12 42 00					Followed about 20 minutes later by several series of waves and about 4 hours of tremors.
		M	12 44 00	19		*200		
		C	12 47 ..	20				
15		i	3 52 ..					Volcanic disturbances on Mauna Loa. Recorded by all three variometers of the magnetograph.
		M	3 53 18			*2,100		
		F	4 04 ..	18				
15		eP	17 50 00					
		L	17 52 48					
		M	17 58 00	19		*300		
		C	17 59 30					
		F	18 28 ..					
18		P	14 11 18					Local shock: recorded by magnetograph. Followed by tremors for about 5 hours.
		M	14 12 00			*300		
		C	14 13 18					
		F	14 14 ..					
26		eP	9 28 48					Several irregular series of waves.
		L	9 38 30					
		M	9 56 ..	17		$300		
		F	10 22 ..	18				
26		P	19 52 00					Secondary maximum at 22 : 39 and at 23 : 48.
		eL	20 16 06					
		M	20 31 24	19		*1,900		
		C	20 38 30	18				
		F	23 53 ..	18				
27		L	4 10 00					
		M	4 15 38	18		*100		
		C	4 18 30					
		F	4 42 ..					
29		eP	12 37 00					Tremors continue to next quake.
		L	12 40 00					
		M	12 40 48	18		*400		
		C	12 44 30					
29		L	13 49 12					Eruption of Mauna Loa.
		M	13 49 42	17		*100		
		C	13 52 ..	19				
		F	14 09 ..					
30		L	7 56 30					
		M	7 59 30	17		*100		
		F	8 04 ..					

* Trace amplitude.

TABLE 2.—Instrumental seismological reports, *September, 1919*—Continued.

Illinois. *Chicago. University of Chicago.* U. S. Weather Bureau.

Lat., 41° 47′ N.; long., 87° 37′ W. Elevation 180.1 meters.

Instruments: Two Milne-Shaw horizontal pendulums, 0.45 kg.

Instrumental constants		V	T_0	ϵ	Sensitivity.
	E.	150	12	20:1	1″ arc tilt=26.6 mm.
	N.	150	8	20:1	1″ arc tilt=13.2 mm.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			H. m. s.	Sec.	μ	μ	Km.	
Sept. 1		e	13 48 ..					
		L	14 00 ..	20				
		L	14 11 40	15				
		F	14 50 ..					
1		P	19 37? ..					
		S	19 45 15					
		L	19 55 ..	35				
		L	20 06 ..	18				
		F	21 50 ..					
5		P?	19 07 26				3,770	
		S	19 13 10					
		L?	19 16 15					
		F	20 ca ..					
6		P	9 35 30				3,540	
		S	9 40 50					
		L	9 44 ..					
		L	10 03 ..	18				
		L	10 20 ..	15				
		F	11 40 ca					
11		P?	14 00 40					Nearly continuous disturbance, may not be seismic.
		S?	14 03 38					
		L	14 05 40					
		L	14 09 05	12				
		F	15 10 ca					
12		P?	14 01 15					
		S?	14 09 32					
		L	14 23 ..					
		L	14 37 ..	18				
		F	15 10 ca					
13		P	12 29 15				7,750	
		S	12 38 22					
		L	12 51 20	22				
		L	12 58 30	15				
		F	15 10 ca					
15		P	17 36 45				3,700	Irregular waves, complicated by strong microseisms.
		S	17 41 15					
		L	17 45 18					
		M	17 47 30					
		F	18 50 ca		*3,500	*3,000		
16		P?	12 04 22					
		S	12 08 53					
		L	12 15 ..					
		L	12 22 ..	22				
		L	12 30 ..	18				
		F	12 50 ..					
19		P	3 22 19				3,980	
		S	3 28 05					
		L	3 33 15	15				
		F	4 10 ca					
26		P	9 26 26				8,200	
		S	9 35 56					
		eL?	9 50 ..					
		L	10 12 ..	22				
		F	11 30 ..					
26		P?	20 00 28					
		S	20 10 10					
		L	21 06 ..					
		F	23 30 ca					
27		P	3 41 17				3,590	
		S	3 45 40					
		eL	3 50 ..					
		F	4 30 ..					
27		P?	11 13 20					
		S	11 21 58					
		L	11 22 15					
		F	11 35 ..					
30		P	7 42 35				2,730	
		S	7 46 58					
		L	7 49 50					
		F	8 40 ..					

Kansas. *Lawrence. University of Kansas.* Department of Physics and Astronomy. F. E. Kester.

Lat., 38° 57′ 30″ N.; long., 95° 14′ 58″ W. Elevation, 301.1 meters.

Instrument: Weichert.

Instrumental constants		V	T_0	ϵ
	E	177	3.4	4:1
	N	205	3.4	4:1

(Report for September, 1919, not received.)

Maryland. *Cheltenham. Magnetic Observatory.* U. S. Coast and Geodetic Survey. George Hartnell.

Lat., 38° 44′ 00″ N.; long., 76° 50′ 30″ W. Elevation, 71.6 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants		V	T_0
	E	10	14
	N	10	14

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			H. m. s.	Sec.	μ	μ	Km.	
Sept. 6		P	9 34 45	5				
		S	9 38 48					
		M_N	9 39 00			60		
		M_E	9 39 05		80			
		L_E	9 40 40					
		eL_E	9 42 00					
		M_N	9 46 05	13	30			
		M_N	9 49 15	10		20		
		C_N	9 50 ..	10				
		C_E	9 55 ..	10				
		F_E	10 07 ..	10				
		F_N	10 14 ..					
15		eP	17 47 31	5				Uncertain on account of micros.
		L_N	17 49 50					
		L_E	17 50 50					
		M_N	17 50 15	11		30		
		M_E	17 51 10	12	40			
		C	17 52 ..	10				
		F_N	17 56 ..					
		F_E	17 59 ..					
27		eP_E	11 34 03	3				Possibly not seismic.
		eP_N	11 34 28	3				
		F_N	11 38 ..			10		
		F_E	11 39 ..		10			
30		P_N	7 53 42	3				
		eP_E	7 53 46					
		eL_N	7 54 40					
		eL_E	7 57 40					
		M_N	7 54 45	10		30		
		M_E	7 59 05	9	10			
		F	8 03 ..					

Massachusetts. *Cambridge. Harvard University Seismographic Station.* J. B. Woodworth.

Lat., 42° 22′ 36″ N.; long., 71° 06′ 59″ W. Elevation, 5.4 meters. Foundation: Glacial sand over clay.

Instruments: Two Bosch-Omori 100 kg. horizontal pendulums (mechanical registration).

Instrumental constants		V	T_0	ϵ
	E	80	23	0
	N	50	25	4:1

(Report for September, 1919, not received.)

Missouri. *Saint Louis. St. Louis University.* Geophysical Observatory. J. B. Goesse, S. J.

Lat., 38° 38′ 15″ N.; long., 90° 13′ 58″ W. Elevation, 160.4 meters. Foundation: 12 feet of tough clay over limestone of Mississippi system, about 300 feet thick.

Instrument: Wiechert 80 kg. astatic, horizontal pendulum.

Instrumental constants	V	T_0	ϵ
	80	7	5:1

(Report for September, 1919, not received.)

TABLE 2.—Instrumental seismological reports, *September, 1919*—Continued.

New York. *Ithaca. Cornell University.* Heinrich Ries.

Lat., 42° 26′ 58″ N.; long., 76° 29′ 09″ W. Elevation, 242.6 meters.

Instruments: Two Bosch-Omori 25 kg. horizontal pendulums (mechanical registration).

Instrumental constants..	V	T_0	ϵ
E	13	22	4:1
N	14	25	4:1

(Report for September, 1919, not received.)

New York. *New York. Fordham University.* D. H. Sullivan, S. J.

Lat., 40° 51′ 47″ N.; long., 73° 53′ 08″ W. Elevation, 23.9 meters.

Instrument: Wiechert, 80 kg.

Instrumental constants..	V	T_0	ϵ
E	72	5.0	0
N	72	5.0	0

(Report for September, 1919, not received.)

Panama, Canal Zone. *Balboa Heights.* Governor, Panama Canal.

Lat., 8° 57′ 39″ N.; long., 79° 33′ 29″ W. Elevation, 27.6 meters.

Instruments: Two Bosch-Omori, 100 kg.

Instrumental constants..	V	T_0
	35	20

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			H. m. s.	*Sec.*	μ	μ	*Km.*	
Sept. 27	....	P_E	3 35 20				595	
		P_N	3 35 24					
		L_E	3 36 37	20				
		L_N	3 36 41	20				
		M_E	3 36 57		500			
		M_N	3 36 58			1,000		
		F_E	3 46 42					
		F_N	3 49 26					

Porto Rico. *Vieques. Magnetic Observatory.* U. S. Coast and Goedetic Survey. W. M. Hill.

Lat., 18° 09′ N.; 65° 27′ W. Elevation, 19.8 meters.

Instruments: Two Bosch-Omori.

Instrumental constants..	V	T_0
E	10	17
N	10	19

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			H. m. s.	*Sec.*	μ	μ	*Km.*	
Sept. 5	....	P	19 03 02					Local.
		eL_E	19 03 15					
		eL_N	19 03 44					
		M	19 04 02	5-10	80	130		
		F	19 11 ..					
6	....	iL	9 30 15					Recorded on magnetogram. Probably local.
		M_N	9 31 18	16		1,890		
		M_E	9 31 23	16	1,590			
		C	9 34 ..	7				
		F	10 06 ..	6				
11	....	P_N	13 50 10	3				Local.
		P_E	13 50 13					
		L_E	13 50 27					
		L_N	13 50 36					
		M	13 50 52	8	90	60		
		C	13 52 ..	4				
		F_N	13 57 ..	4				
		F_E	14 00 ..					
11	....	iP_N	14 13 00					Local.
		P_E	14 12 01					
		eL_N	14 12 06					
		eL_E	14 12 07					
		M	14 12 43	8	120	130		
		C	14 14 ..	5				
		F_N	14 19 ..	4				
		F_E	14 23 ..	4				
13	....	eP_E	12 32 00					Times uncertain for lack of time marks. Barely a trace on N-S.
		M_E	12 38 40	20	20			
		F_E	12 58 ..					

Porto Rico. *Vieques Magnetic Observatory*—Continued.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
13	....	eP_N	21 49 51	2				Local.
		P_E	21 49 52					
		L_E	21 50 09					
		L_N	21 50 22					
		M	21 50 28	7	60	40		
		C	21 51 ..	4				
		F	21 57 ..	4				
25	....	iP	16 21 46					Local.
		M	16 21 48		30	50		
		F	16 25 ..					

Vermont. *Northfield. U. S. Weather Bureau.* Wm. A. Shaw.

Lat., 44° 10′ N.; long., 72° 41′ W. Elevation, 256 meters.

Instruments: Two Bosch-Omori, mechanical registration.

Instrumental constants..	V	T_0
E	10	15
N	10	16

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			H. m. s.	*Sec.*	μ	μ	*Km.*	
Sept. 6	....	e	9 36 20					
		S	9 39 44					
		eL	9 45 ..					
		F	10 00 ..					
30	....	e	7 57 ..					
		F	8 05 ..					

Canada. *Ottawa. Dominion Astronomical Observatory.* Earthquake Station. Otto Klotz.

Lat., 45° 23′ 38″ N.; long., 75° 42′ 57″ W. Elevation, 83 meters.

Instruments: Two Bosch photographic horizontal pendulums, one Spindler & Hoyer 80 kg. vertical seismograph.

Instrumental constants..	V	T_0
	120	26

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			H. m. s.	*Sec.*	μ	μ	*Km.*	
Sept. 1	....	e_N	19 30 36 to 20 00 ..					
		eL_E	20 06 ..					
		eL_E	20 10 .. to 20 25 ..	18				
6	....	eL?	9 40 18 to 10 00 ..	11				Early phases los in microseisms L waves very irregular.
		L?	10 16 ..	13				Very irregular.
		F	10 40 ..					
13	....	i_V	12 21 40					Character of L waves not sinusoidal. Very irregular. Do not resemble usual earthquake records.
		i_N	12 29 40	5				
		i_E	12 38 04	9				
		$eL?_E$	12 45 ..					
		L_E	12 50 ..	28				
		L	12 56 ..	18				
		F	13 30 ..					
15	....	i_E	17 39 14					Heavy microseisms.
		e_N	17 49 20 to 18 00 ..	6				
		F	18 10 ..					
19	....	e_E	3 29 ..					Small waves resembling large micros.
		e_N	3 40 .. to 4 00 ..					
26	....	i_N?	9 26 20					The first impulse may not be due to the earthquake. It appears isolated from the L waves.
		eL_N?	10 06 .. to 10 10 ..					
		L	10 16 .. to 10 25 ..	18				
26	....	eL	20 36 .. to 20 42 ..	30				Preceded by slight tremblings extending over several hours. No trace of phase. May be micros. L waves are certainly seismic.
		L / L	20 47 .. to 20 55 ..	25				
		L	21 00 .. to 21 05 ..	22				

TABLE 2.—*Instrumental seismological reports, September, 1919*—Continued.

Canada. *Ottawa. Dominion Astronomical Observatory*—Continued.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
26		L	21 07 .. to 21 16 ..	17				
		L	21 20 .. to 21 25 ..	17				
		F	21 50 ..					
27		O?	3 34 32				4,080	
		$eP?_N$	3 41 56					
		PR_1	3 43 36					
		$eS_N?$	3 47 48					
		eL	3 55 ..	22				
		L_E	4 00 .. to 4 05 ..	20				
		L	4 20 .. to 4 25 ..	17				
		F	4 30 ..					

Canada. *Toronto. Dominion Meteorological Service.*

Lat., 43° 40′ 01″ N.; long., 76° 23′ 54″ W. Elevation, 113.7 meters. Subsoil: Sand and clay.

Instrument: Milne horizontal pendulum, North; in the meridian.

Instrumental constant T_0..18. Pillar deviation, 1 mm. swing of boom=0.45″.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			H. m. s.	*Sec.*	*μ*	*μ*	*Km.*	
Sept. 1		L?	20 10 10		*100			icros going on.
6		S?	9 36 00					
		L	9 41 06					
		eL	9 43 36					
		M	9 45 00		*1,700			
		F	10 37 54					
13		L	11 37 12					Doubtful as to being seismic.
		eL	11 39 36					
		M	11 40 30					
		F	11 46 30					
13		i	12 19 06					Very difficult seismogram to read.
		i	12 20 48					
		S?	12 25 18					
		L	12 34 24					
		L	12 38 30					
		L	12 45 06					
		L	12 53 54					
		eL	12 55 48					
		M	12 57 24		*800			
13		L	14 21 42					Doubtful, but some strong seismic features.
		eL	14 37 18		*200			
		M	14 37 42					
15		e	17 44 24					
		eL	17 48 48					
		M	17 52 30		*300			Micros going on.
		F	Micros.					
19		L	3 28 42?					
		L	3 31 24?		*50			
22		L	11 40 06		*200			Doubtful as to being seismic.
26		e	9 28 24?					
		L	9 37 06		*100			Do.
		L	9 40 42					
26		L	21 00 12					
		L	21 07 48					
		eL	21 10 00					
		M	21 11 24		*300			
		L	21 25 36					
27		M	4 08 23		*100			
		F	4 14 46					
27		i	3 51 18					
		L	3 52 48					
		eL	3 53 48					
		M	3 57 42		*800			
		F	4 21 42					
30		L	7 53 25		*500			
		F	8 01 18					

*Trace amplitude.

Canada. *Victoria, B. C. Dominion Meteorological Service.*

Lat., 48° 24′ N.; long., 123 19′ W. Elevation, 67.7 meters. Subsoil: Rock.

Instrument: Wiechert, vertical; Milne horizontal pendulum, North. In the meridian.

Instrumental constant T_0..18. Pillar deviation, 1 mm. swing of boom=0.54″.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			H. m. s.	*Sec.*	*μ*	*μ*	*Km.*	
Sept. 1		L	20 04 46					
		M	20 07 13		*300			
		F	20 13 07					
6		P	9 49 48					
		L	9 58 10					
		M	10 05 04		*500			
		F	10 38 59					
13		P	12 32 30					
		S	12 41 21					
		L	12 53 39					
		M	13 11 22		*500			
		F	13 58 34					
15		P	17 46 20					Off coast of California.
		S	17 47 19					
		L	17 49 08					
		M	17 50 46		*400			
		F	17 59 38					
19		M	3.40 11		*200			
		F	3 49 02					
22		L	11 36 32		*50			Doubtful as to being seismic.
26		L	20 04 50					
		M	20 13 41					
		F	22 07 47		*400			Probably Honolulu.
27		M	4 08 23		*100			
		F	4 14 46					
30		P	7 45 52					
		L	7 47 50					
		M	7 49 17		*300			
		F	7 54 12					

*Trace amplitude.

SEISMOLOGICAL DISPATCHES.[1]

Alicante, Spain, September 10, 1919. (2 p. m.)

At 11:40 this morning, and with one second interval, two very intense earthquake shocks, of two seconds duration, were felt here. About fifteen minutes later two similar ones were felt. No damage reported as yet. (Special dispatch.)

Murcia, Spain, September 10, 1919. (6 p. m.)

During the last hours of the morning strong shocks began to be felt. At 1:30 p. m. the oscillations repeated but not as strongly. About 3 p. m. the earthquake was felt again, this time more violently. (Special dispatch.)

Alcony, Spain, September 10, 1919.

At 11:45 an oscillation was felt, which was repeated at 12 o'clock. It was of very short duration. (Special dispatch.)

Cartagena, Spain, September 10, 1919.

During this day several seismic movements were felt. They reached the number of five. The first was of three minutes duration. The last one was more intense than the others. (Special dispatch.)

Rome, Italy, September 12, 1919.

Several villages in the province of Siena were severely shaken last night by an earthquake. Houses collapsed or were badly damaged at Bagni, Asciana, Montorio, Radicofani, Pian Castagnajo, Badia, San Salvatore, and Celle. (Associated Press.)

Copenhagen, September 12, 1919. (Belated.)

A violent earthquake occured at Edinger, a town in Wurtenberg, Germany, Wednesday night, it was reported here today. (Associated Press.)

[1] Reported by the organization indicated and collected by the seismological station at Georgetown University, Washington, D. C.

Honolulu, September 27, 1919.

Mauna Loa volcano on Hawaii Island, burst into eruption to-day at nearly the same spot as the eruption in 1916. (Associated Press.)

Fort De France, September 26, 1919.

A strong earthquake shock was felt here at 12:30 this afternoon. No damage reported. (Associated Press.)

TABLE 3.—*Late reports.* (*Instrumental.*)

District of Columbia. *Washington. Georgetown University.* F. A. Tondorf, S. J.

Lat., 38° 54′ 25″ N.; long., 77° 04′ 24″ W. Elevation, 42.4 meters. Subsoil: Decayed diorite.

Instruments: Wiechert 200 kg. astatic horizontal pendulums, 80 kg. vertical.

Instrumental constants	V	T_0	ϵ
E	165	5.4	0
N	143	5.2	0
Z	*80*	*3.0*	*0*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			H. m. s.	*Sec.*	″	μ	*Km*	
Aug. 29		eP_E	6 06 17					Heavy microseisms.
		eP_N	6 06 28					
		eL_E	6 26 00	17				
		eL_N	6 26 12	17				
		F	8 00 ..					
31		e_E	17 39 22					
		e_N	17 40 26					
		S_E	17 51 00					
		eL	18 05 24	11				
		F	19 10 ..					
			Vertical.					
29		*eP*	*6 06 28*					
		L	*6 56 06*	*19*				
		F	*8 00 ..*					

Hawaii. *Honolulu. Magnetic Observatory.* U. S. Coast and Geodetic Survey. Frank Neumann.

Lat., 21° 19′ 12″ N.; long., 158° 03′ 48″ W. Elevation, 15.2 meters.

Instrument: Milne seismograph of the Seismological Committee of the British Association.

Instrumental constant..T_0 18.1. Sensitiveness 0.40″ arc tilt = 1 mm.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			H. m. s.	*Sec.*	μ.	μ.	*Km.*	
Aug. 3		L	18 43 ..					Beginning during daily routine.
		M	18 48 ..	18	*100			
		C	18 51 ..					
		F	19 27 ..					
18		P	17 03 42					Maximum of all waves at 17h 10m 42s.
		iS	17 09 30	17	*1600			
		eL	17 16 00					
		M	17 32 00					
		C	17 37 ..					
		F	18 10 ..	18				
23		L	16 36 ..					
		M	16 42 ..		*100			
		F	16 45 ..					
24		L	5 28 18					
		M	5 34 00	15	*100			
		F	5 37 ..					
27		eP	5 29 42	17				
		S	5 37 30	15				
		L	5 48 00					
		M	5 55 12	18	*1900			
		C	6 01 ..	17				
		F	6 55 ..	19				
28		eL	20 16 ..					
		M	20 27 ..	19	*100			
		F	20 32 ..					
29		eP	6 00 00					P faint. Record not clear.
		S	6 05 30	17				
		L	6 27 00					
		M	6 31 12	18	*5400			
		C	6 38 ..	16				
		F	8 32 ..	18				
29		eP	14 02 06					
		eS	14 08 00					
		eL	14 14 00					
		M	14 19 00	15	*200			
		C	14 21 ..	15				
		F	14 45 ..	19				
31		iP	17 29 24	19				
		eL	17 40 00					
		M	17 43 00	18	*8800			
		C	17 58 ..	16				
		F	20 25 ..	16				

* Trace amplitude.

TABLE 3.—*Late reports (Instrumental).*—Continued.

New York. *Ithaca, Cornell University.* Heinrich Ries.

Lat., 42° 26′ 58″ N.; long., 76° 29′ 09″ W. Elevation, 242.6 meters.

Instruments: Two Bosch-Omori, 25 kg., horizontal pendulums (mechanical registration)

Instrumental constants	V	T_0	ϵ
E	13	22	4:1
N	14	25	4:1

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			H. m. s.	*Secl.*	μ.	μ.	*Km.*	
June 29		eP_N	23 20 11	4				
		eP_E	23 20 28	3				
		iS_N	23 25 14	9				
		e_E	23 27 28	7				
		F_E	24 25 ..					
30		L_E	8 28 05	20				
		F_E	8 36 ..					
Ju		eP_N	7 11 12	3				
		eS	7 16 25	7				
		L_N	7 20 30	27				
		F	7 40 ..					
8		L_N	21 59 30	18				
		F_E	22 41 ..					
9		e_N	19 27 25	4				
		eL_N	19 37 42	7				
		F_N	20 02 ..					
11		e_N	0 39 30	3				
		e_N	0 42 32	5				
		e_E	0 42 48	5				
		Lz_N	0 45 22	8				
		F_N	0 57 ..					
17		P_N	16 26 20	3				
		eS_N	16 31 46	5				
		eS_E	16 31 56	4				
		eL_E	16 37 04	12				
		eL_N	16 38 43	20				
		F_N	16 56 ..					
22		P_E	22 07 56	2				
		P_N	22 07 57	2				
		S_E	22 12 53	5				
		S_N	22 12 55	5				
		L_E	22 15 05	5				
		L_N	22 15 11	6				
		F	22 24 ..					
Aug. 18		eP_N?	17 15 36	4				Microseisms.
		S_E	17 21 15	5				
		S_N	17 21 18	8				
		L_N	17 24 11	9				
		L_N	17 29 05	13				
		F	17 43 ..					
24		L_E	6 02 ..	12				
		F	6 04 ..					
29		eP_N?	6 06 04	5				Microseisms.
		e_N	6 27 15	4				
		e_E	6 32 58	10				
		e_N	6 37 50	18				
		L_N	6 51 07	30				
		L_E	6 54 53	22				
		F	7 54 ..					
30		e_N	13 13 53	7				May not be seismic.
		L_N	13 22 56	9				
		F	13 33 ..					
31		eP_E	17 41 12	4				
		e_E	17 47 53	12				
		eS_E?	17 50 47	12				
		e_N	17 57 10	9				
		e_E	17 58 18	18				
		eL_E	18 07 15	20				
		eL_N	18 12 10	36				
		F	19 02 ..					

TABLE III.—*Late reports (instrumental)*—Continued.

Canada. *Ottawa. Dominion Astronomical Observatory.* Earthquake Station. Otto Klotz.

Lat., 45° 23′ 38″ N.; long., 75° 42′ 57″ W. Elevation, 83 meters.

Instruments: Two Bosch photographic horizontal pendulums, one Spindler & Hoye 80 kg. vertical seismograph.

Instrumental constants. V 120 T_0 26

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			H. M. S.	Sec.	μ	μ	Km.	
Aug. 29		i	6 06 47					Record of a distant earthquake. The first phases are lost in small micros.
		e_N	6 12 33					
		e	6 15 52					
		e_N	6 23 50					
		eL?	6 46 ..	23				
		L	6 52 ..	30				
		L	7 05 ..	20				
		L	7 15 ..	18				
		L_E	7 25 ..	17				
		L	7 40 ..	18				
		L_N	7 45 ..	24				
		L_E	7 45 ..	18				
		F	8 10 ..					
31		o?	17 28 47				8,540	N.-S. and E.-W. records very dissimilar. Very difficult to read.
		eP_N?	17 39 20					
		iP_E	17 40 35					
		e_E	17 47 08					
		eS_E?	17 50 23					
		e	17 48 30					
		e	17 51 10					
		eL_N?	18 07 ..					
		eL_N	18 10 30	40				
		L	18 30 ..	18				
		L	18 40 ..	16				
		L	18 48 ..	16				
		L_E	19 30 ..	16				
		F	20 00 ..					

Canada. *Toronto. Dominion Meteorological Service.*

Lat. 43° 40′ 01″ N.; long., 79° 23′ 54″ W. Elevation, 113.7 meters. Subsoil: Sand and clay.

Instrument: Milne horizontal pendulum, North; in the meridian.

Instrumental constant.. T_0 18. Pillar deviation, 1 mm. swing of boom = 0.45″.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
Aug. 13								Minute microseisms from 0h to 7h. Impossible to detect movement recorded at other station from 0h 41m.
18		iL	5 31 24?					Doubtful as to being seismic.
		M	5 31 45		*200			
		F	5 35 00					
18		L?	17 25 24					Early phases lost attending instrument.
		L	17 31 30					
		M?	17 33 42?		*200			
		eL	17 53 54					
24		L	5 15 12		*100			
		F	5 18 48					
24		iL?	5 29 18					
		M	5 29 36		*200			Last phase gradual thickening.
		eL	5 35 48					
		L	6 00 36?					
		F	6 05 36					
24		L	12 45 54					
		L	12 58 54		*50			

Canada. *Toronto. Dominion Meteorological Service*—Continued.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
Aug. 27		L?	5 45 48					
		L	5 59 48					
		L	6 19 12					
		eL	6 23 18					
		M	6 34 30		*300			
		F	?					
29		e?	5 58 42					Possibly 2 earthquakes, overlapping.
		e	6 06 48					
		L	6 16 18					
		L	6 34 54					Small micros make interpretation difficult.
		L	6 50 48					
		i	6 54 36					
		i	6 55 24					
		eL	6 57 00					
		M	7 09 30		*2,300			
29			14 34 33					Micros while quake was recorded at other station.
29		L	14 36 12		*100			Micros going on.
31		L	0 39 24		*100			Do.
31		i?	17 51 36					
		eL	18 20 24					
		eL	18 21 30					
		eL	18 25 42					
		M	18 29 12		*2,400			
		F						Do.

* Trace amplitude.

Canada. *Victoria, B. C. Dominion Meteorlogical Sesvice.*

Lat., 48° 24′ N.; long., 123° 19′ W. Elevation, 67.7 meters. Subsoil: Rock.

Instrument: Wiechert, vertical: Milne horizontal pendulum, North. In the meridian

Instrumental constant.. T_0 18. Pillar deviation, 1 mm. swing of boom = 0.54″.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
Aug. 13		L	0 41 00					
		F	0 45 12		*50			Minute thickening.
18		M	17 17 06		*300			
		F	18 07 46					
24		M	5 16 30		*300			
		F	5 47 30					
24		M	12 43 40		*100			
		F	12 49 00					
27		P	5 42 19					
		S	5 46 45					
		L	?					
		M	6 08 24		*900			
		F	6 56 05					
29		P	6 02 03					Phases well defined.
		S?	6 08 27					
		L	6 12 00					
		M	6 12 23		*700			
		L	6 18 54					
		F	?					
29		L	6 34 30					Do.
		M	6 42 22		*1,500			
		F	8 30 34					
29		P	14 34 33					
		M	14 40 27		*50			
		F	14 46 21					
31		P	0 29 12					
		L	0 34 36					
		M	0 37 32		*50			
		F	0 45 25					

* Trace amplitude.

Chart XVII. Weather Map of North Atlantic Ocean, September 13, 1919. (Plotted by F. A. Young.)

Chart XVII. Weather Map of North Atlantic Ocean, September 13, 1919.
(Plotted by F. A. Young.)

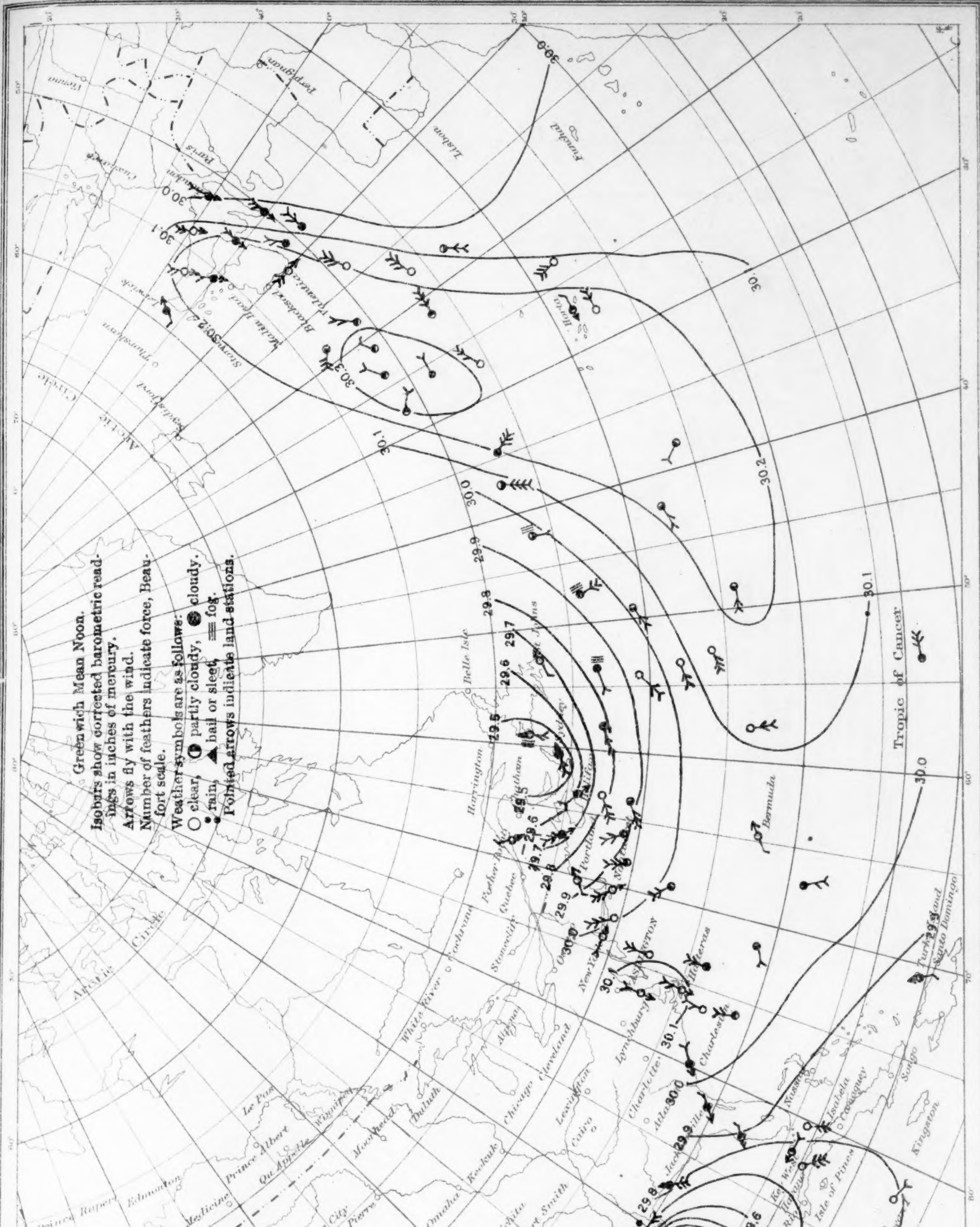
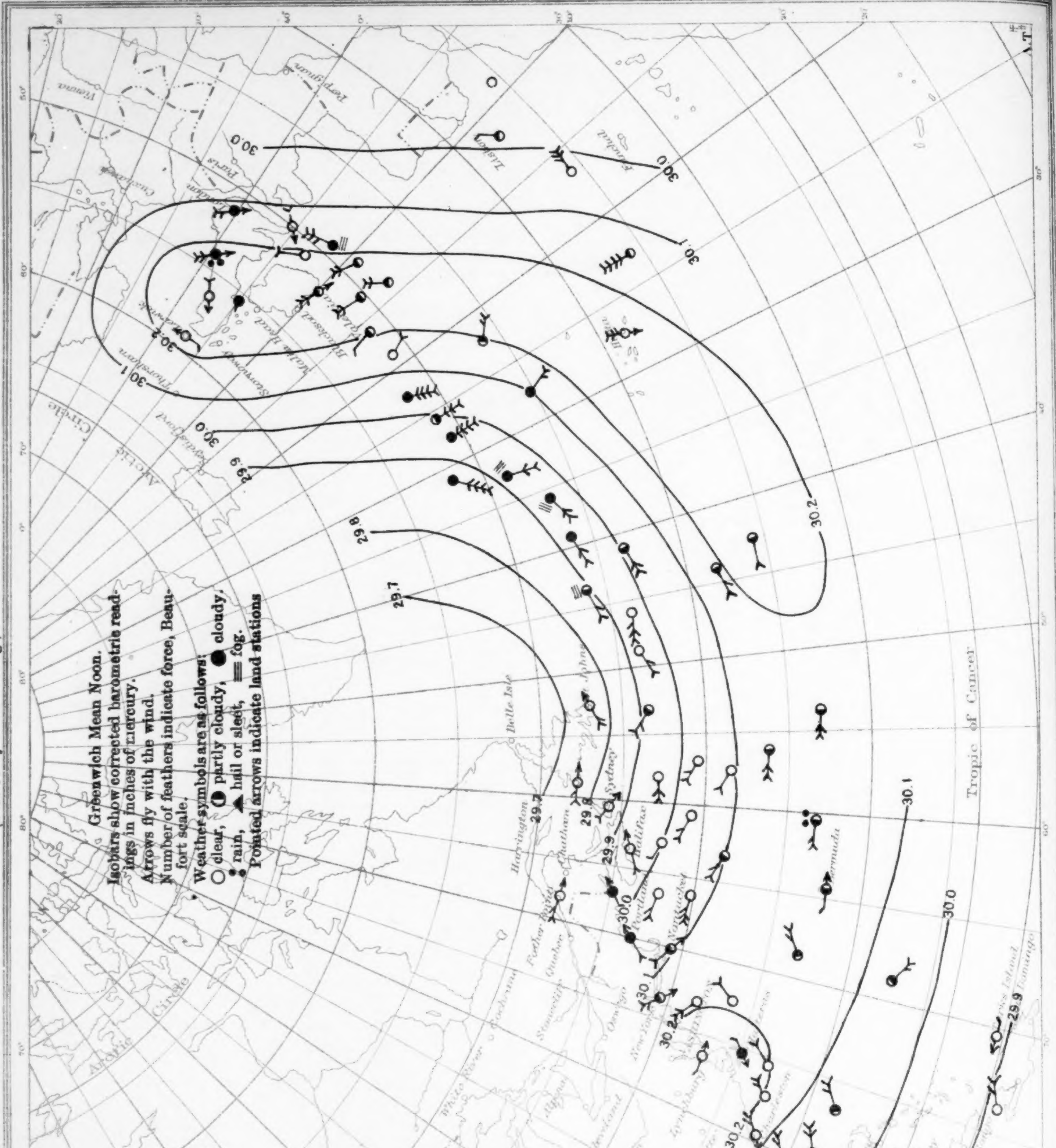


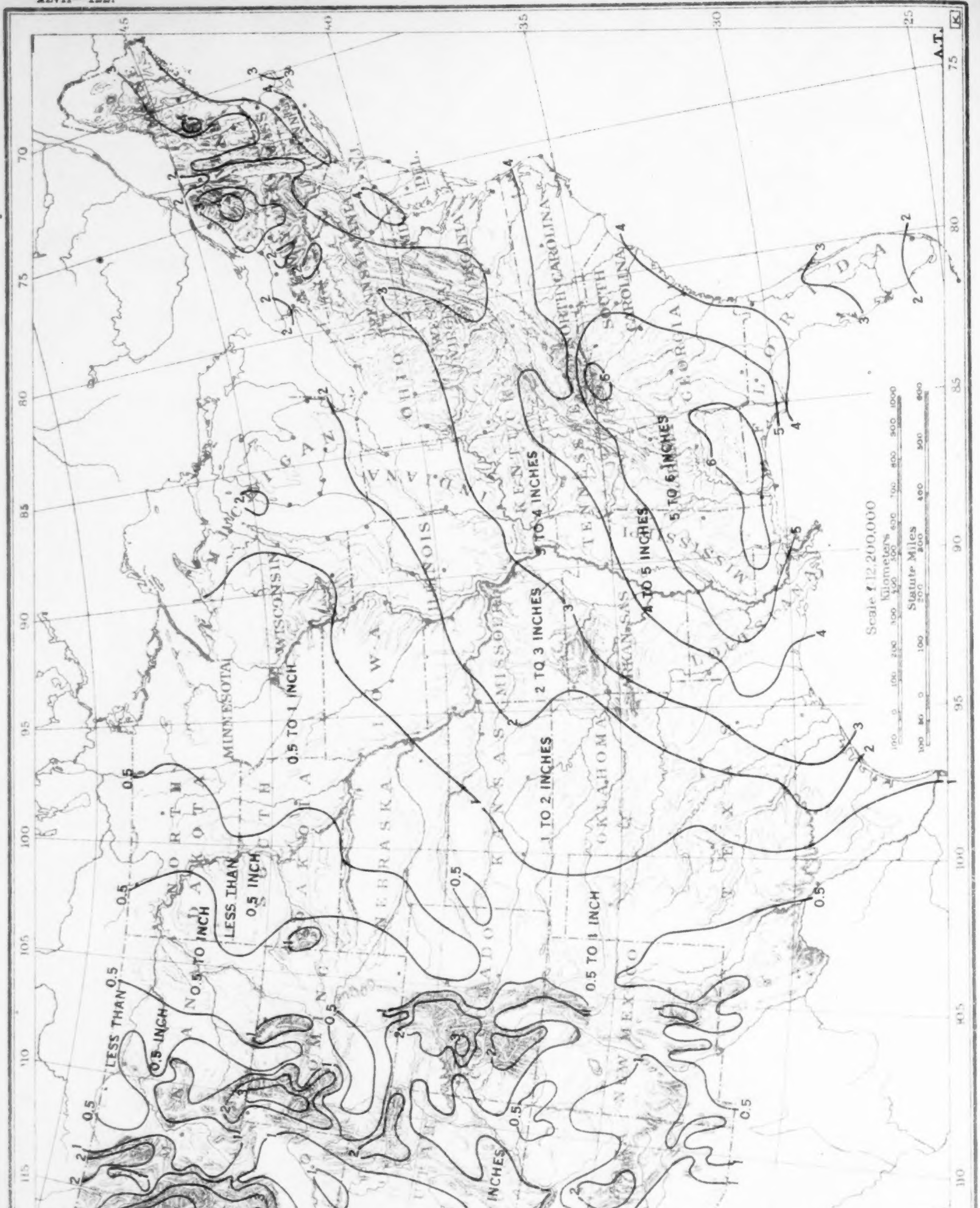
Chart XVIII. Weather Map of North Atlantic Ocean, September 14, 1919.

(Plotted by F. A. Young.)

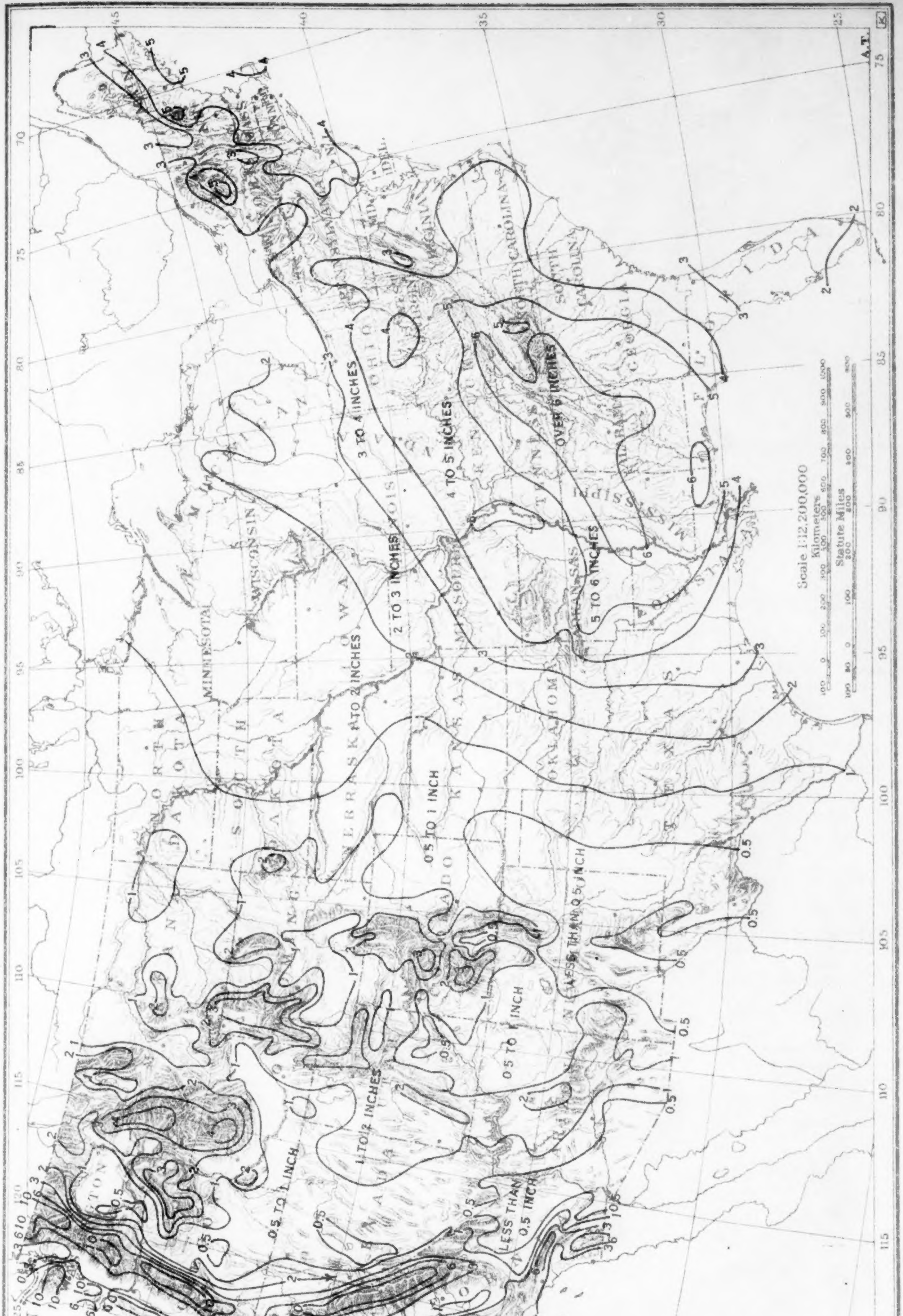


J. B. K. Chart I.—Average January Precipitation, Inches.

J. B. K. Chart II.—Average February Precipitation, Inches.

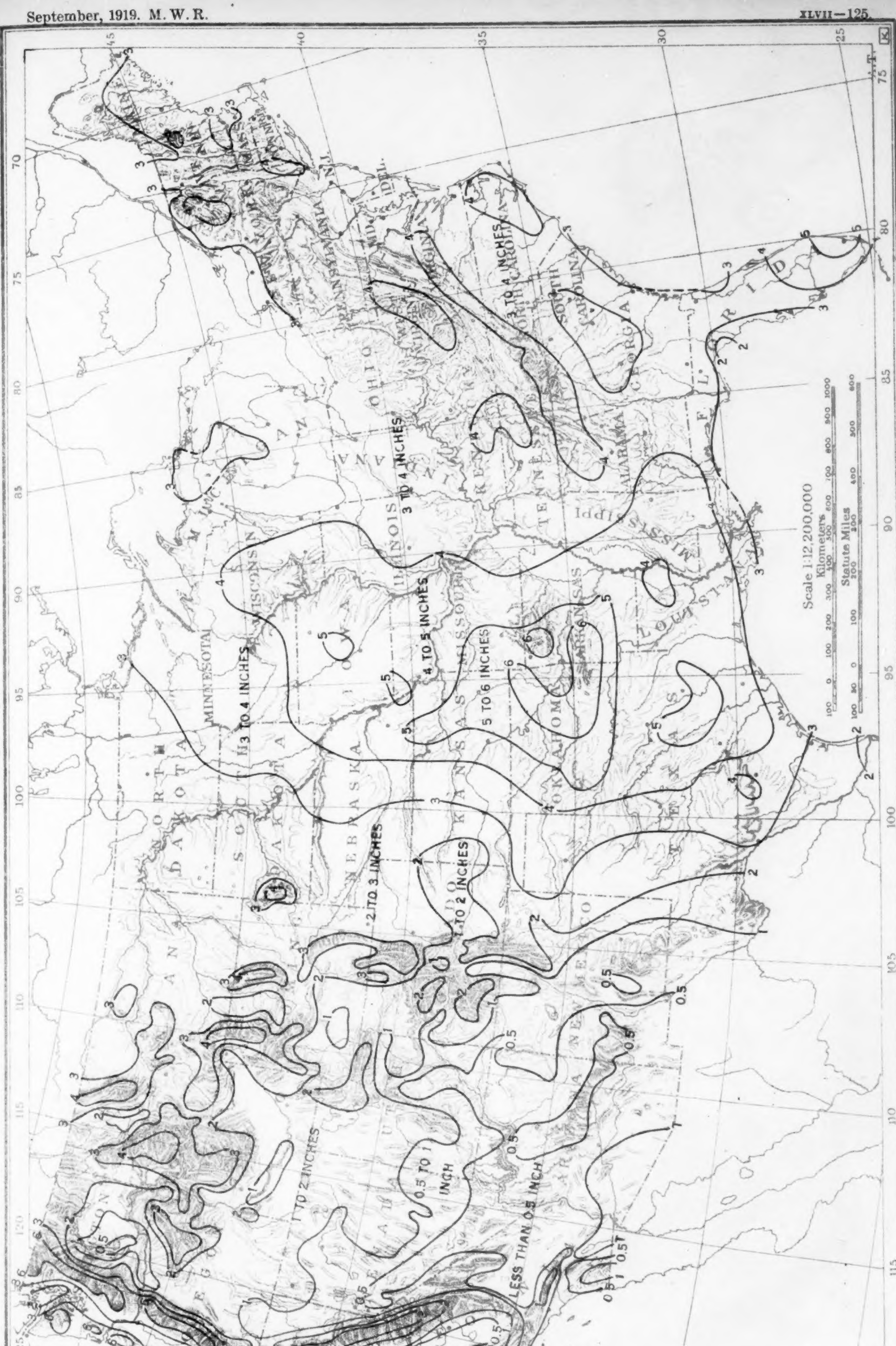


J. B. K. Chart III.—Average March Precipitation, Inches.

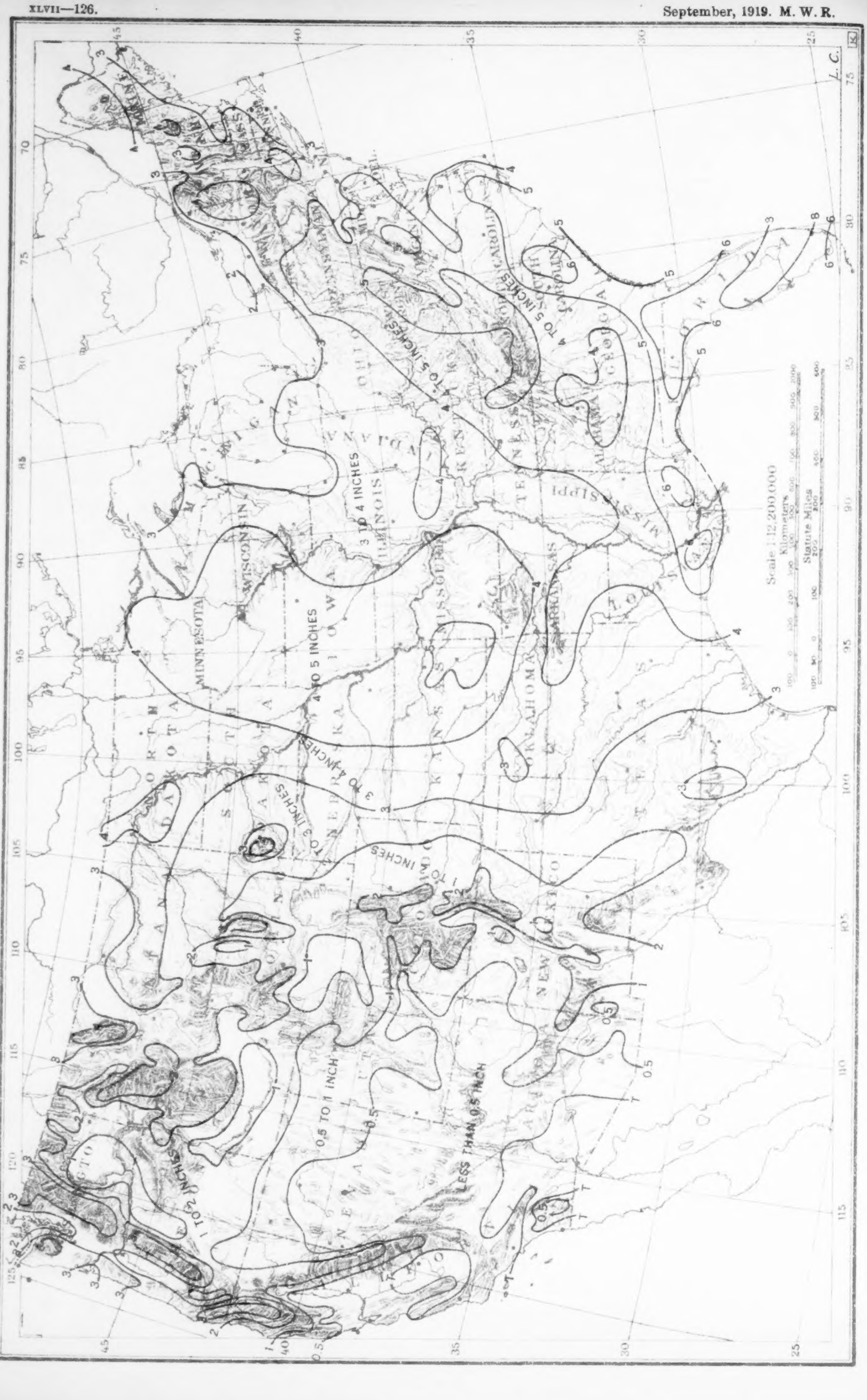


J. B. K. **Chart IV.—Average April Precipitation, Inches.**

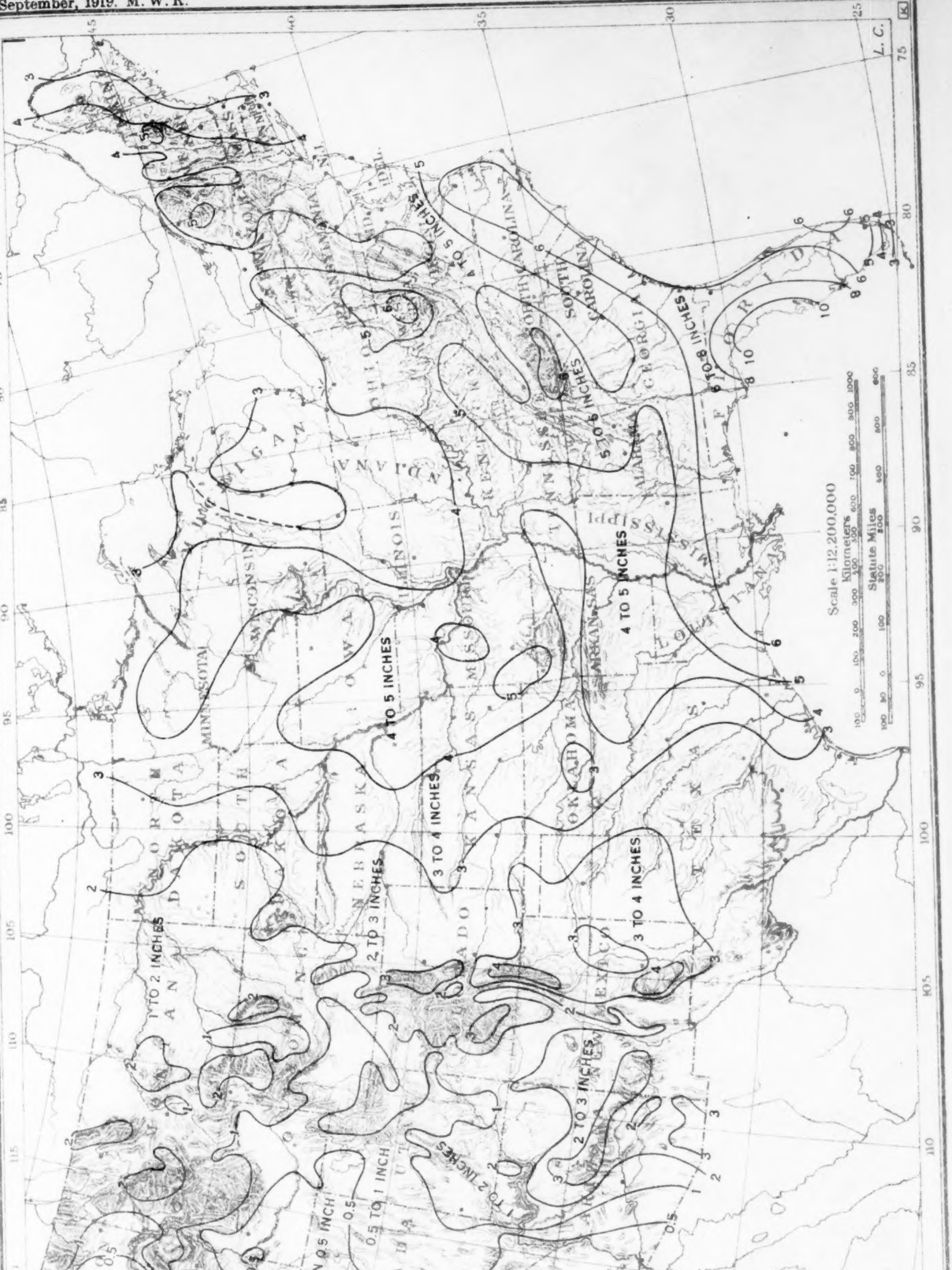
J. B. K. Chart V.—Average May Precipitation, Inches.



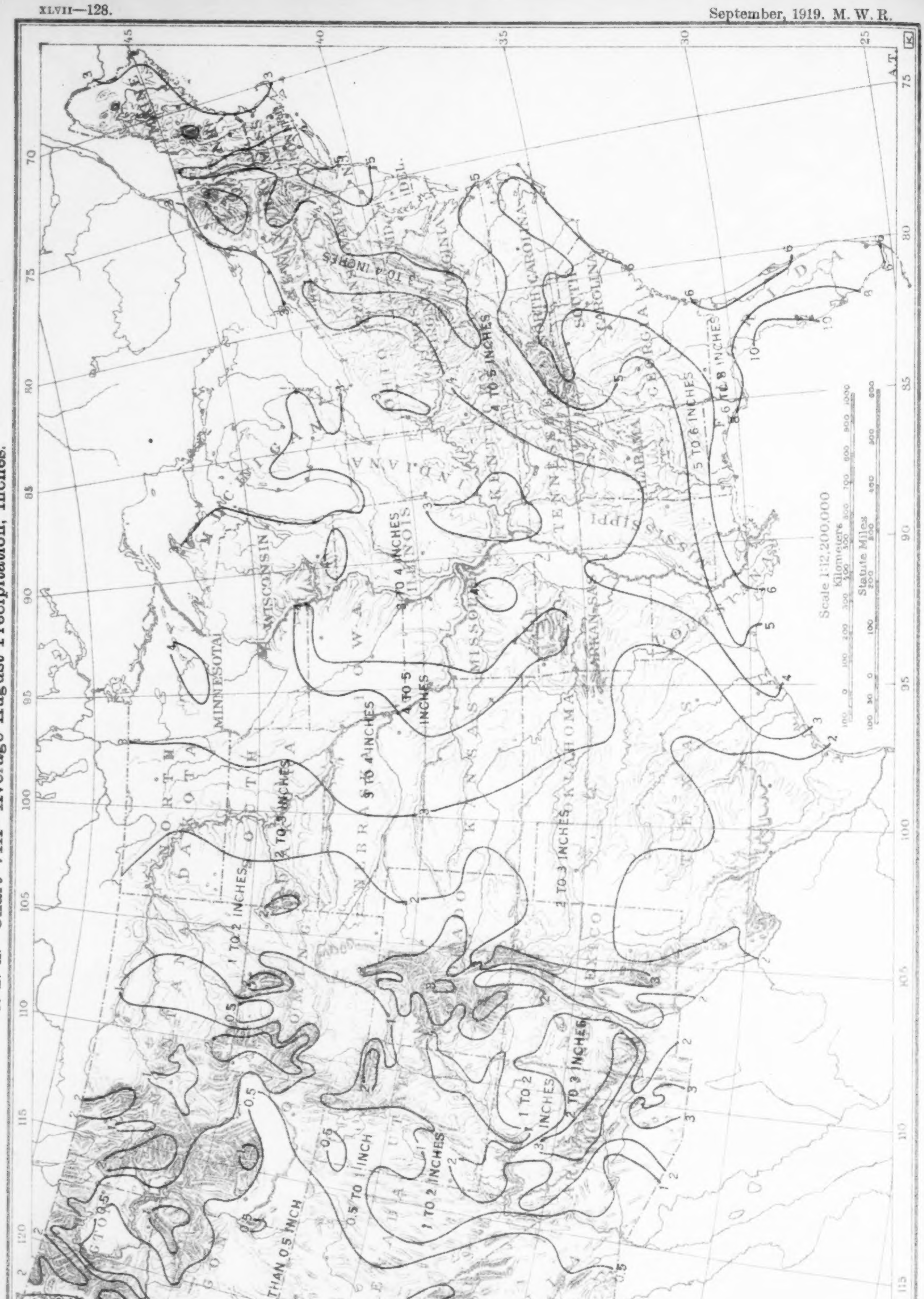
J. B. K. Chart VI.—Average June Precipitation, Inches.



J. B. K. **Chart VII.—Average July Precipitation, Inches.**

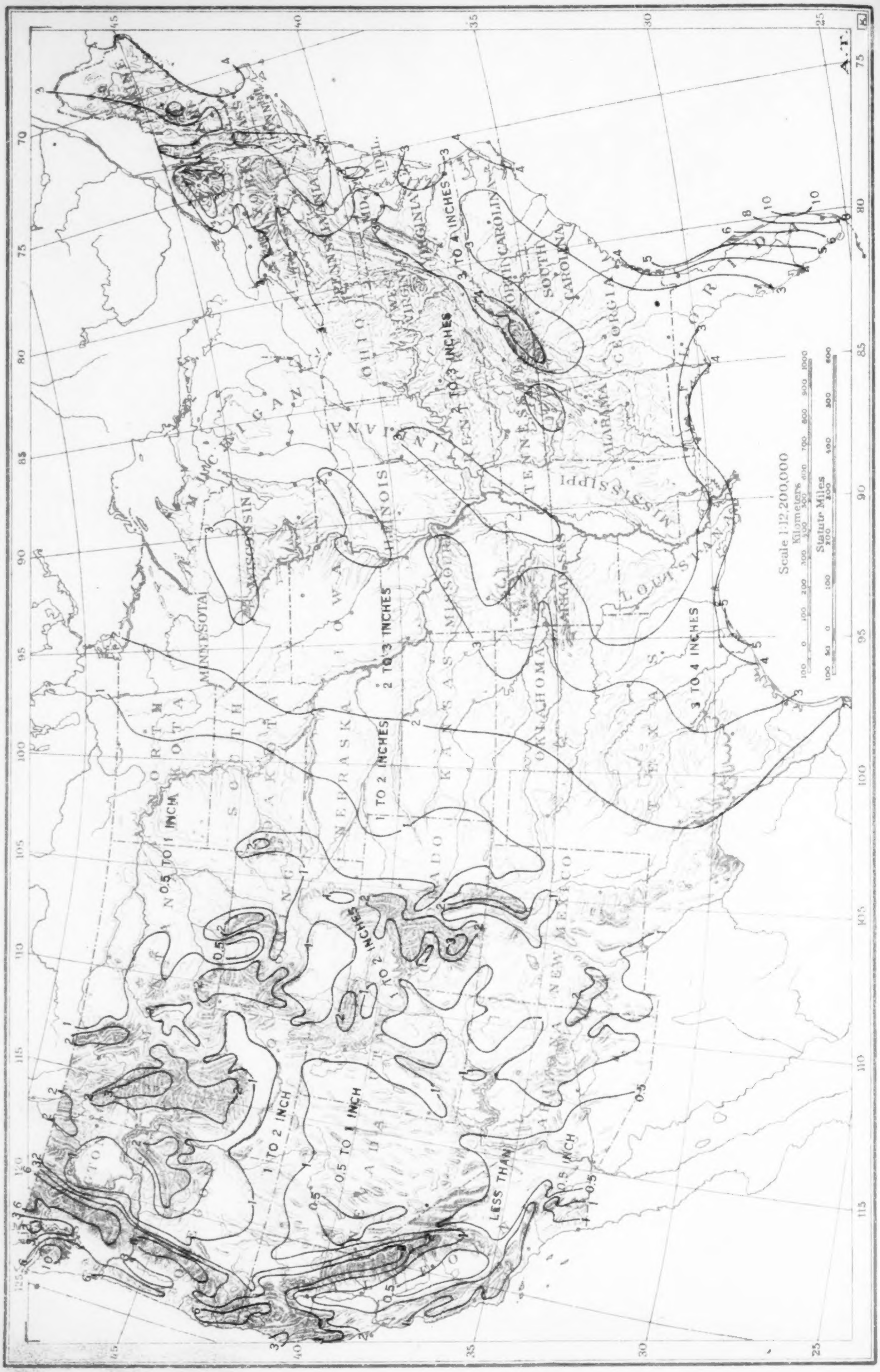


J. B. K. **Chart VIII—Average August Precipitation, Inches.**

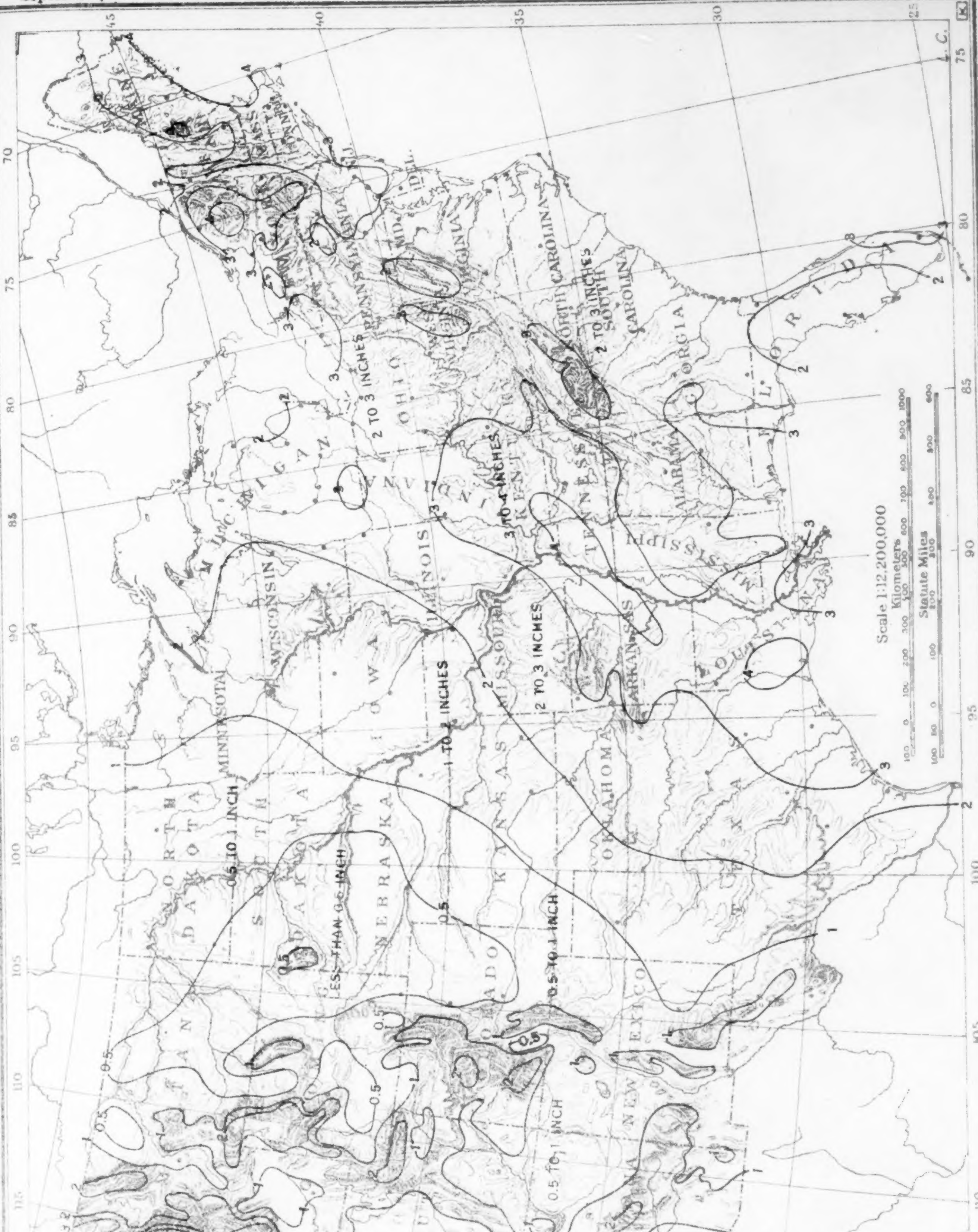


J. B. K. Chart IX.—Average September Precipitation, Inches.

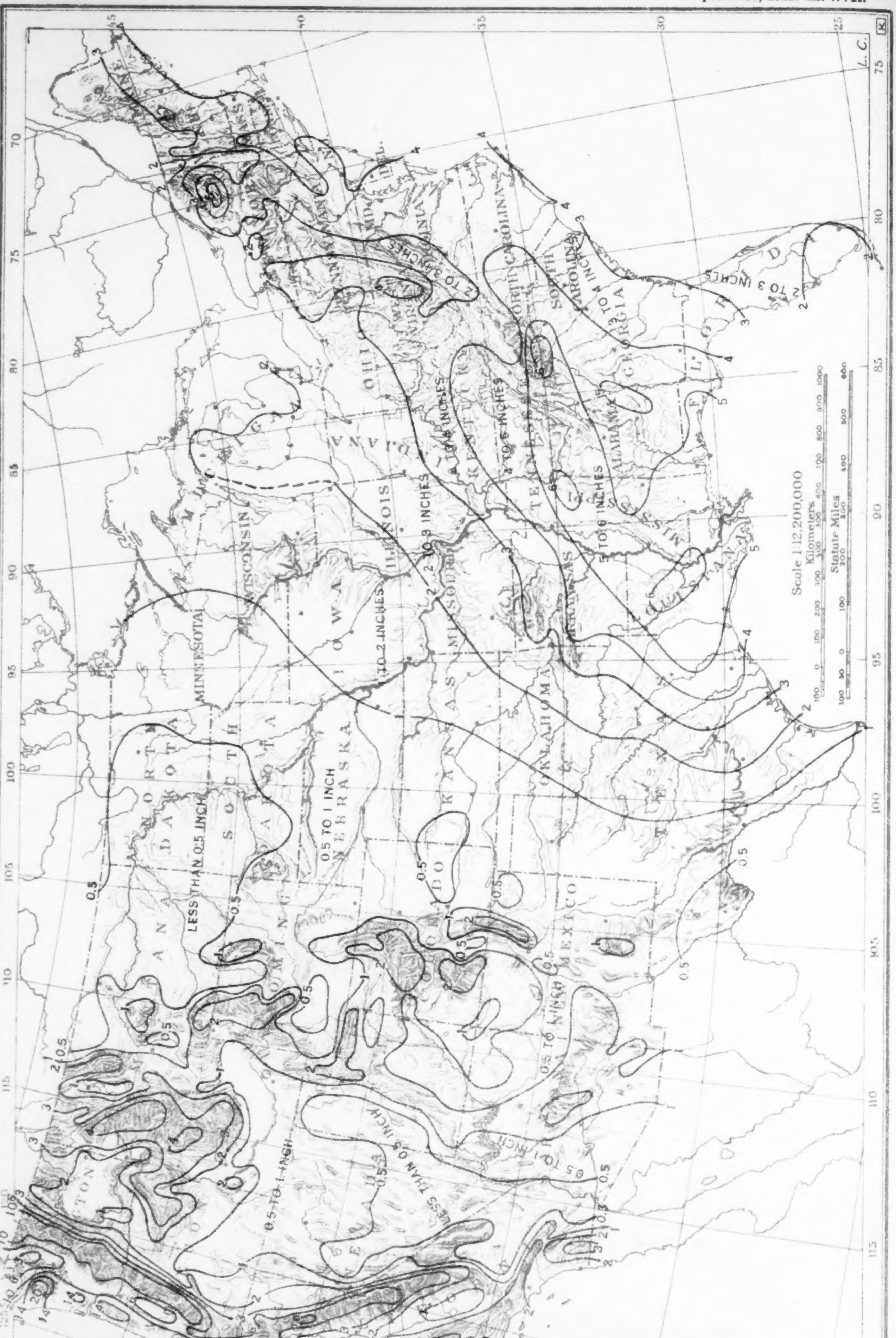
J. B. K. Chart X.—Average October Precipitation, Inches.



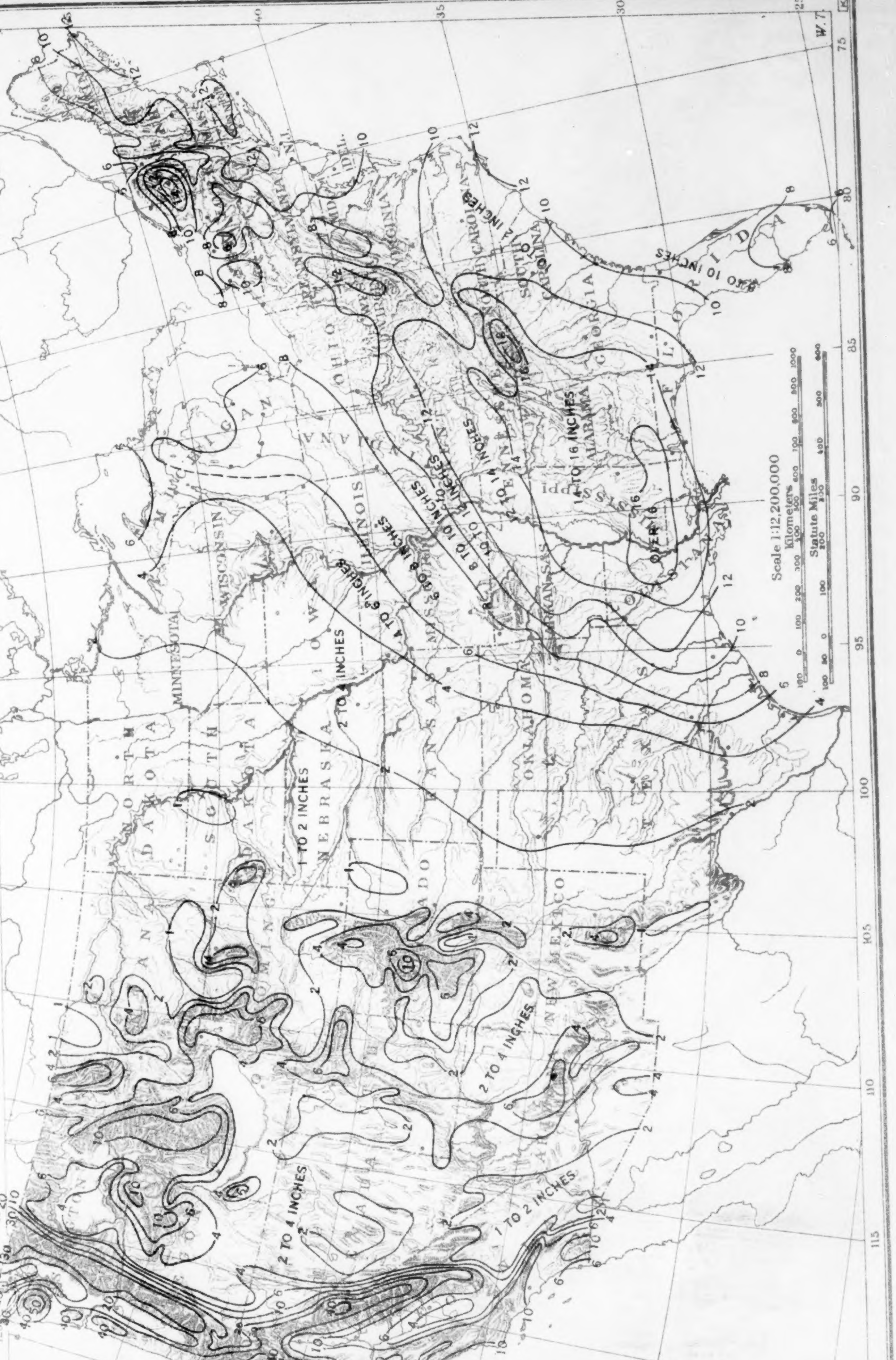
J. B. K. Chart XI.—Average November Precipitation, Inches.



J. B. K. Chart XII.—Average December Precipitation, Inches.

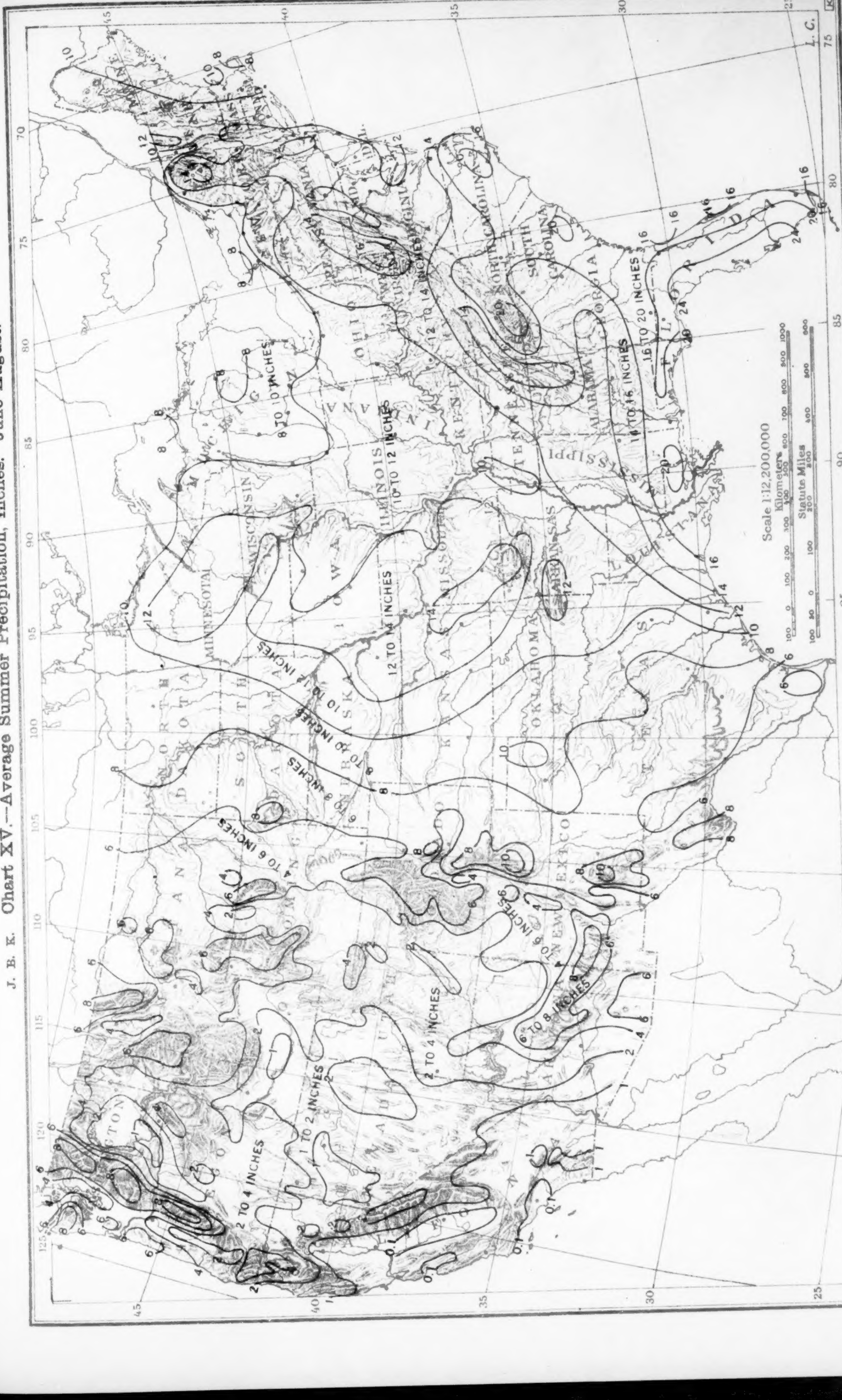


J. B. K. Chart XIII.—Average Winter Precipitation, Inches. December-February.

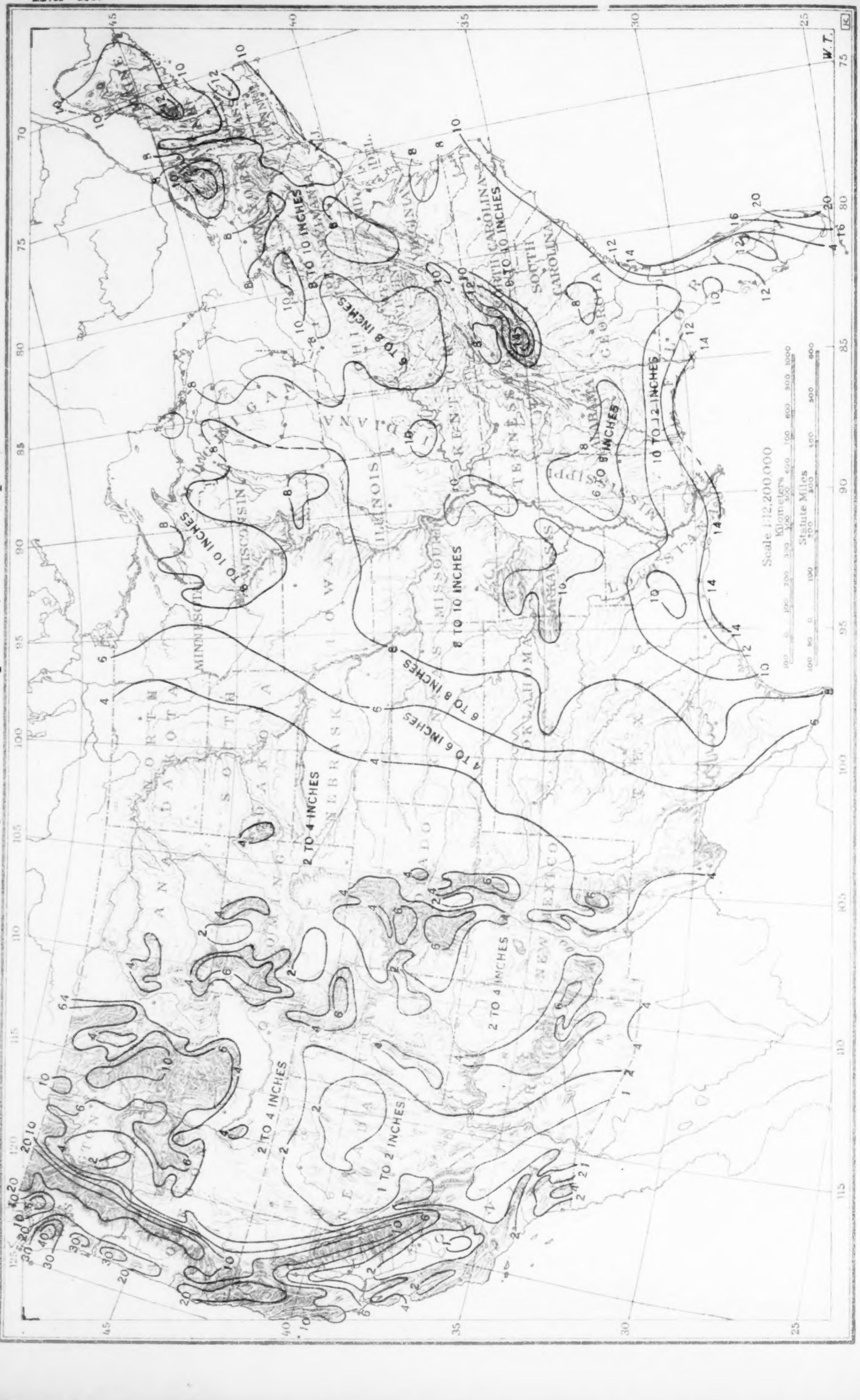


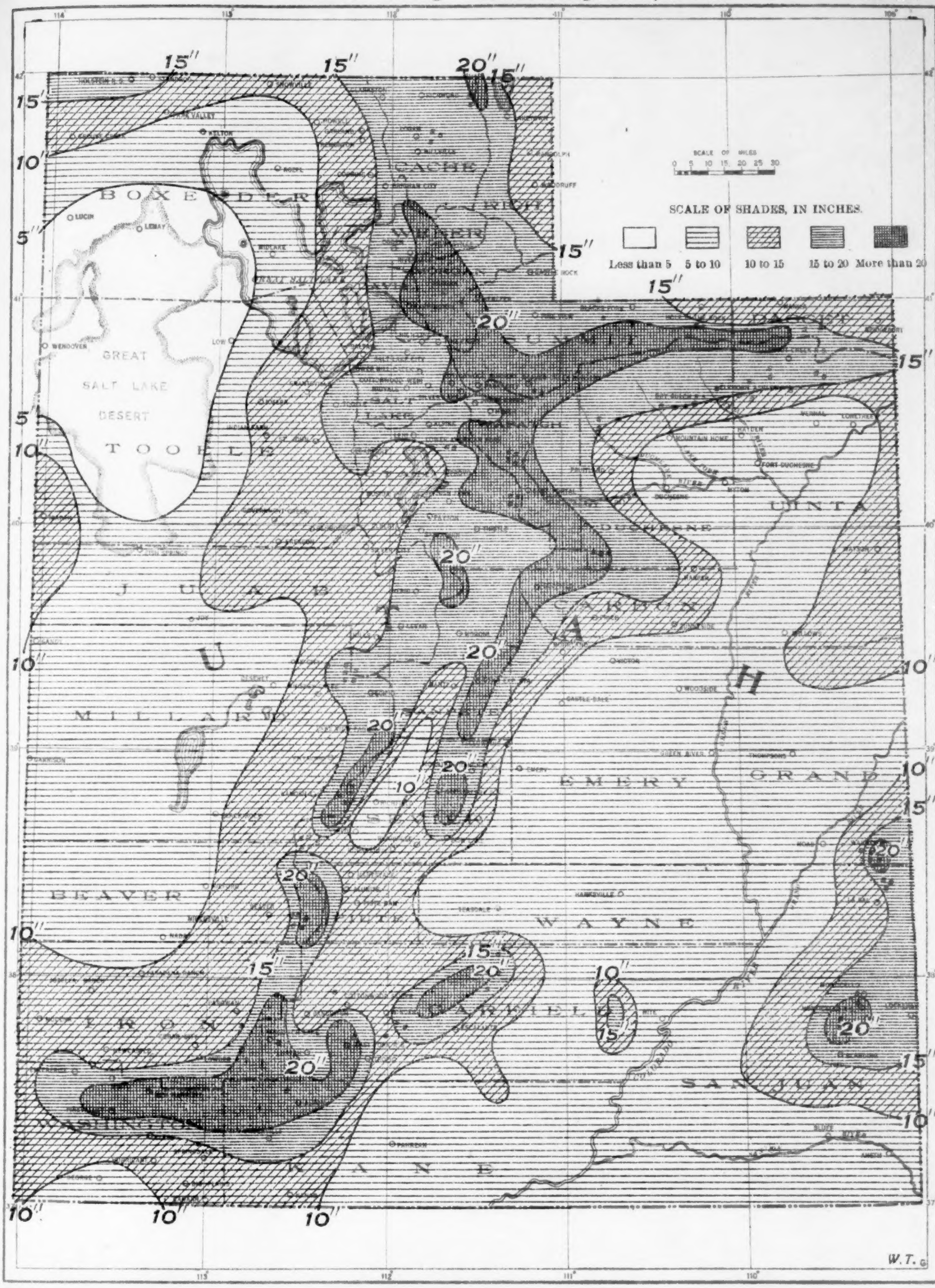
J. B. K. Chart XIV.—Average Spring Precipitation, Inches. March–May.

J. B. K. Chart XV.—Average Summer Precipitation, Inches. June-August.



J. B. K. Chart XVI.—Average Autumn Precipitation, Inches. September–November.





September, 1919. M. W. R.